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RADIO TALKS ON SCIENCE[1]

THE ATOM

By Dr. PAUL D. FOOTE

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Good evening, radio listeners. Every one of you, on some bright starry evening, has stood with awe and wonder gazing at the grandeur of the celestial bodies, these countless numbers of worlds, the distances of which from our own earth are almost beyond comprehension. Each star is undoubtedly the sun in a solar system about which planets revolve, and upon some of which possibly life and intelligence exist.

Even more wonderful, however, are the miniature planetary systems of the atoms, the infinitesimal building blocks entering into the construction of every material substance. We know the sizes of these atoms, even though they are so small that the figures expressing their dimensions mean little to the average individual.

A molecule is larger than an atom. A molecule of water, for example, contains two atoms of hydrogen and one atom of oxygen. Let me illustrate how many molecules are contained in a tumblerful of water. Suppose we could label every molecule in the tumbler for future identification. We then pour the glass of water into the ocean and wait until all the water on the earth is thoroughly mixed. After this, the tumbler is refilled from the nearest hydrant. How many of the original molecules do you suppose would be found in this second glass of water? The surprising answer is two thousand. If figures can convey an impression of the size of an atom, let me

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point out that in one pound of copper there are forty-three million million million million atoms—that is, the figure forty-three followed by twenty-four ciphers.

In spite of the minute size, it is possible to weigh an individual atom with an accuracy far greater than that used by your grocer in selling sugar. Although an atom is very much smaller than the most minute particle of matter which can be seen under a microscope, yet we possess means for counting individual atoms, and we are able to determine the number in any piece of metal or matter with a precision greater than that possible in enumerating the population of a large city.

Although an atom is so extremely small, still it is an involved mechanical system in itself, consisting of a minute, complicated sun about which a certain number of planets revolve. In the atomic planetary system, the planets are all exactly alike and are negative charges of electricity called electrons. These electrons are identical with those emitted by the glowing filament in the vacuum tubes of your radio receiving set. By direct experiment we can measure the charge on a single electron, the mass of an electron, and are able to determine with accuracy the total number of electron planets in any piece of matter. The sun in the atomic planetary system is a highly concentrated positive charge of electricity, its total charge, expressed in terms of the electronic charge as a unit, being equal to the number of planetary electrons present. For example, a single atom of copper contains a sun with a positive charge of twenty-nine units surrounded by twenty-nine electron planets. In the atom of hydrogen we have a sun with one unit of positive charge about which a single electron revolves. An atom of gold has seventy-nine electrons and the most complicated atom, uranium, has ninety-two electron planets. Our own solar system consisting of the sun and eight planets resembles, in a very rough way, an atom of oxygen.

Very peculiar things may happen to the revolving planetary electrons. Two or more atoms may approach so closely together that their planetary systems interlock, thereby forming a molecule or chemical compound. A meteor, for example, another electron, may penetrate into the atomic system and collide with one of the planets so vigorously as to eject the planet completely from the system. Or the meteor may eject one of the planets a small distance out into a new orbit. The rearrangements following disturbances of this kind are manifested by the emission of radiation. If one of the inner planets is disturbed, X-rays are emitted. Disturbance of an outer planet, corresponding to Neptune in our solar system, gives rise to light or heat radiations.

We have seen that an element is characterized by a sun possessing a definite charge of from one to ninety-two units of positive electricity, surrounded by planetary electrons, some of which may be comparatively easily removed or disturbed. An atom of radium has a sun with eighty-eight positive charges and eighty-eight revolving electrons. Two of these planets are readily removed in chemical reactions, such as the formation of radium chloride. The atom, however, is still radium. That is, the real difference between any two elements is not the number of planetary electrons, but the charge on the sun about which these planets revolve. Now the sun in an atomic system, contrary to our own solar system, is a very complicated affair. In fact, the atomic sun itself is a planetary system consisting of closely packed positive and negative charges. If some of these component parts of the sun are ejected, the atom is transmuted into a new element. Such transformations are taking place spontaneously in nature. Radium is transmuted into a gas which in turn becomes a new element, a solid. Uranium is slowly turning into radium, and radium eventually becomes ordinary lead. Some forty different alchemical transmutations occur spontaneously among the radioactive elements—all occasioned by changes in the minute atomic sun.

It has been possible within the past two years to transmute certain elements artificially in the laboratory by processes where the atomic sun may be disintegrated. For example, phosphorus has been transmuted into silicon and hydrogen; aluminium has been transmuted into magnesium and hydrogen, and many elements, such as boron, nitrogen, fluorine and others, have been transmuted artificially. In fact, we undoubtedly know how to transmute any element whatever, but at present are limited in many cases by the difficulty in constructing the apparatus necessary for such experiments. There is no reason why gold may not be made from mercury; just as wonderful transmutations already have been effected.

So far these artificial transmutations of the elements have been very inefficient. The cost of producing gold from mercury by the present methods suggested would be immeasurably greater than the value of the gold. The only interest in modern alchemy, in its present state of development, is purely scientific. However, there are possibilities, perhaps mere idle dreams of the scientists, that some of these transmutations may eventually prove of value to the welfare of humanity. There is plenty of power stored in these minute planetary systems—the problem is to get it out efficiently. If the hydrogen in only six teaspoonsful of water could be transmuted into helium, energy should be liberated sufficient to propel the battleship *California* across the Atlantic Ocean. If the secret

of this transmutation be discovered, we need have little concern for the present rapid exploitation of our oil and coal fields.

We, at the Bureau of Standards of the Department of Commerce, however, are not investigating the atom with the hope of realizing such astounding possibilities. It is necessary better to understand the atom and the electron for more modest and more immediate purposes. We have in this country entire industries, the functioning of which is dependent upon the caprices of a quantity of electricity so minute as an electron. Long-distance telephonic communication, with or without wires, the X-ray or Coolidge tube used for medical purposes, the production of illumination such as the arc lamp and the more efficient operation of industrial processes involving photochemical synthesis and decomposition, photo and photographic chemistry, electrochemistry, the chemistry of gaseous reactions—all these industrial processes are such that real progress, both in the art and in protective safety devices, is conditioned by our knowledge of the changes which may take place in the interior of an atom.

CARVING THE SCIENTIFIC POSSUM

By Professor ERNEST MERRITT
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THE title of this talk was suggested, in a manner which may not be at once obvious, by an old song that was popular during my boyhood. I do not intend to sing it, for the musical side of the radio program is well taken care of without my assistance. In fact, except for the central motif of the song, I have entirely forgotten it. There were twenty or thirty verses, each ending with the refrain, "Carve that possum," and all devoted first to a eulogy of roasted possum and then to a description of the proper method of preparing it. The process of preparation was described at length, with detailed instructions for each step. Certainly no one could listen to that song—much less sing it—without being convinced that roast possum was a most desirable and appetizing dish.

And there was a logical sequence in the thing that impressed me greatly. In giving his instructions the writer did not plunge into the middle of things, but started at the beginning and went on step by step to the sweet and succulent end. The beginning appealed to my youthful common sense—and appeals even now to my more mature common sense—as a very proper one. If condensed into form suitable for a cook book it would have read "First, *catch* your possum!"

One could not help realizing that unless this first piece of advice was followed the rest of the song might as well be left unsung and there would be no occasion to "carve that possum." To my mind that was the motif of the song.

Now it is pretty evident that this same common-sense advice to first catch your possum may properly be applied to a number of other things, sometimes even more important than possums. My intention is to show how it applies to science.

No one in these days needs to be reminded of the importance in modern life of applied science. Try to imagine what our civilization would be like if we had no steam engines, no electric light or telephone or telegraph, none of the metals that the chemists have shown us how to obtain, or the dyes or medicines that they are able to prepare, none of the serums and antitoxins that help to prevent and to cure disease. All these things and thousands of others—practically everything of a material kind that makes our life different from that of the dark ages—are the result of applying scientific knoweldge.

It is applied science that makes our modern civilization possible. But there can be no applied science until there is science to apply. That is the point which it seems to me needs stressing. First catch your possum. *Then* cook him and prepare him for the table. Finally carve him and give every one his fair share.

Strange to say, it is only in recent years that the importance of this essential first step has been realized in this country. We have had many skilled cooks to prepare and serve the scientific possum, but relatively few hunters to bring in the raw meat. Fortunately the situation is changing. But many still fail to realize how essential is the foundation of pure science upon which the inventor or the applied scientist must build.

Let me give a very obvious illustration: Many of us can remember the time when incandescent lamps with a filament of tungsten took the place of lamps with a carbon filament. The change resulted in a much better lamp and a saving of hundreds of millions of dollars. The development of the tungsten filament lamp is one of the triumphs of applied science.

But if some chemist had not already discovered tungsten and shown how to get it out of its ore this particular triumph would not have been possible. First catch your possum. The hunter who first detected this particular possum was a German. The one who brought down the game was a Spaniard; and chemists all over the world had been studying his peculiarities for over a hundred years before the cooks began to prepare him for the table. So far as I know every great advance in applied science has a similar history.

No cook, however skilful, can prepare a meal unless he has at hand the raw materials. No inventor, however ingenious, can make an invention without using the materials and the knowledge which pure science has provided for him.

Besides furnishing the raw materials there is another way in which scientific knowledge helps the inventor: it shows him the *possibility* of practical applications. Suppose that some Roman emperor had felt the need of rapid communication with his army or with some distant province and had called upon the engineers and inventors of his day to find a method. They would probably have suggested runners like the original Marathon runner, or men on swift horses, or perhaps a series of men sending messages by smoke signals or flags from one mountain top to another. Would any one have thought of sending messages by means of wires? Would any one have dreamed of such a thing as the emperor's talking to his people as President Coolidge spoke to the people of America on March fourth? It isn't until we know that there is such an animal as a possum that we can even dream of using him to prepare a meal.

If we study the history of great inventions we always run across another fact that is common to all, but which at first seems so strange that we can hardly believe that it is always true: namely, that the most essential part of the scientific foundation on which the inventor builds was developed without reference to practical applications and with no thought of the use to which it is later put. When Scheele discovered tungsten he was not hunting for a means of improving the incandescent lamp and reducing the cost of electric lighting. In his day there was no incandescent lamp to improve. Artificial light was furnished by candles and by lamps burning sperm oil. The discoverer of tungsten had not the remotest idea what the practical uses of the new metal would be. He did not know whether it had any practical use; and in fact it wasn't until a hundred years later that any practical use was found. We do not know any more than Scheele did what the future uses of tungsten may be.

In most cases practical application does not wait quite so long after scientific discovery as in the case of tungsten. The electric telegraph was made possible by Oersted's discovery of the magnetic effect of the current and followed this discovery in about forty years. Radio telegraphy was made possible by Hertz's discovery of electric waves in 1890. Nine years later, in 1899, Marconi had sent messages across the British channel and twelve years later, in 1902, across the Atlantic. The first use of radium for the treatment of cancer followed its discovery by about three years. The

use of X-rays in surgery came almost immediately after the rays were discovered. I have a very vivid recollection of using X-rays only a few months after their discovery in the attempt to locate a safety pin which a squirming and indignant baby was supposed to have swallowed. We can feel pretty certain nowadays that a big scientific discovery will be followed by practical applications within a few years.

But even if the applications do not come soon enough to benefit us they will surely be of use to our children. We don't know what the applications will be, but we can feel absolutely sure that they are on the way.

The scientific worker of course gets a good deal of satisfaction out of the conviction that every scientific discovery is sure to be ultimately of practical value. But I very much doubt whether that is his chief stimulus to scientific work. I have compared the scientific discoverer to the hunter who finds the possum and kills him so that the cook may have his raw material. Of course many men earn their living by hunting. But unless they enjoy hunting for its own sake they are not likely to be very successful, and will probably choose some other occupation. There are plenty of jobs that pay better than hunting possum and are not such hard work. The same thing is true with the job of hunting scientific possum.

I imagine that the real stimulus to scientific discovery is simply curiosity. We may dignify it by the name of scientific curiosity if you like, but it isn't essentially different from plain everyday curiosity. Take, for example, the early history of electricity. If we trace back any of our applications of electricity, from electroplating to radio, we finally come to a man in ancient Greece who noticed that when he rubbed a piece of amber on his toga it would attract things. Now what was it that led him to study this curious behavior and so to launch the science of electricity? Was he thinking of dynamos and silver-plated spoons and long distance telephony? Not by any means. He was simply interested and amused by something which probably seemed to him of very little importance, but which nevertheless aroused his curiosity. For two thousand years the science of electricity was kept alive and slowly progressed because of this same sort of scientific curiosity. *Now* we are coming to realize that curiosity of that kind pays. It doesn't pay the scientific discoverer. I never heard of a discoverer becoming wealthy. But scientific curiosity pays the world as a whole. It may be that it was curiosity that killed the cat; but for human beings it is a very desirable quality. Without it material progress would slow up and finally stop. So when your little boy uses his new knife to remove the polish from the grand piano or goes after

an alarm clock with a hammer in order to find out what is inside, it may seem wise to guide his activity into other channels, but don't chide him too severely. When this curiosity of his gets its growth you may find that he is a scientist.

Now I have rambled on for nearly the whole of my allotted time and have hardly made one serious remark. But there really is a purpose to this talk, namely, to point out that so far as their bearing on material progress is concerned pure science and applied science stand or fall together. Pure science is of no practical use until it is applied. But without pure science applications are impossible.

If we wish to continue roast possum as a part of our regular diet, even after the supply now on the market is used up, we must make sure that the scientific possum hunters keep on the job. Let us give them reasonably comfortable tents to live in, good weapons to hunt with, and above all plenty of ammunition; and let us recognize that they, like the waiters and the cooks, are doing their part toward making the feast a success.

METEORS

By Dr. GEORGE P. MERRILL

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A FEW months ago, on a bright, cloudless day in midsummer, a funeral was being held in the churchyard of a little town in the west. In the midst of the services there came from the sky four terrific explosions followed by shrill, whistling sounds and sounds like those of an airplane, and smokepuffs were seen high in the air; then a quantity of rock fragments, the largest weighing nearly forty pounds, came to the ground and buried themselves in the earth. Naturally many of the people were much frightened at such a bombardment taking place at the time and under the conditions mentioned, and some were disposed to regard it with a considerable degree of superstition. In the light of history, however, the matter has become commonplace, not that such incidents occur with great frequency, but that during the past centuries of observation a great many records have accumulated and we now know that masses of stone or metal may fall from space. Where they come from we are not prepared to say definitely, but of what they are we are now fully cognizant, and we call them meteorites.

Now before going further I want to call attention to what to my mind is a very interesting feature of meteorite falls and which

to the public at large is little appreciated. While we were taught as school children that the weight of the atmosphere is such as to exercise a pressure of approximately fifteen pounds to each square inch of surface, it was not very firmly impressed upon us that this pressure might be enormously increased by the motion of either the air or that of a body moving in the air, itself quiet. We are brought to a realization of it, however, when we stagger against a March gale of wind, or ride on the front seat of a rapidly moving automobile. We guard against it by windshields and goggles and we now know that it is only speed and incidental air pressure that keeps an airplane afloat. But these speeds are tame compared with that of a meteor which often comes into our atmosphere traveling at a rate of from twenty-five to fifty miles a second, or fifty to one hundred times as fast as the swiftest projectile from our most powerful pieces of ordnance. Picture to yourself, then, a solid body plunging downward into our atmosphere under such conditions. What happens? There will be brought to bear upon it a pressure of not less than 10,000 pounds per square inch, and the meteorite, if of friable stone, is crushed to fragments, as when a boy throws a snowball against a brick wall. If the meteorite is of iron it may withstand the pressure, but in either case it catches fire and may be completely consumed. Out of the millions of meteors that come into our atmosphere every day a very large proportion of them are burned up. It is these that form the shooting stars that may frequently be seen on clear, cloudless nights stealing silently across a section of the sky and disappearing. It is only when of sufficient size to escape destruction that they come crashing to earth in the manner I have described. And this gives us opportunity to consider for a moment what might happen to our earth were it not for its protective armor plate of atmosphere. It has been calculated that any iron meteorite must lose 90 per cent. of its substance by being burned away in its passage, while its speed is checked from whole miles a second to that of a body falling merely from the attraction of gravity. Think then of the bombardment to which we would be subjected were there no atmosphere to protect us and the meteorites were ten times as heavy.

As I have stated we are as yet by no means sure where the meteorites come from. The most satisfactory theory would seem to be that they are fragments of comets which have gone to pieces.

It is of interest to review the opinions of some of the earlier workers. A German by name of Chladni more than a hundred years ago advanced the idea that they were but the remains of cosmic matter employed in the formation of worlds. He considered

comets, falling stars, meteoric fire balls and meteorites as all of similar origin and elementary matter.

Wilhelm Olbers, another of the early workers, thought for a time to have demonstrated that they were ejected from volcanoes on the moon. Later he changed his views and thought their source to have been a small planet that once occupied a position between Mars and Jupiter but which has now gone to pieces, leaving in its place four large fragments or planetoids and a myriad of smaller ones which are slowly drifting back to earth in the form of meteorites. Still others have conceived of the moon having been thrown off from the earth in its youthful days and carrying with it a quantity of smaller fragments, which, drifting about in eccentric orbits, are gradually being gathered in once more. Still others look upon them as products of disintegration of a planet blown to pieces by some unexplained and unknown internal force. None of the many suggestions have proved satisfactory in all their detail.

Astronomers tell us that in the far reaches of space beyond our solar system are clouds which obscure the more distant stars, as nearer stars are obscured by thin clouds of vapor. What is the nature of these clouds is wholly speculative. That they are not of water vapor seems certain. May we not with a fair degree of assurance assume that they are composed of fragmental matter like the ejectamenta of a modern volcano and that in time they will be gathered in as meteoric material by neighboring planets. When we consider the aftermath of sun glows due to volcanic dust after the eruption of Krakatoa this should not be a difficult conception and it is an interesting thought, at least, that in the dark, wholly lightless portions of the sky there may to-day be worlds in the making through the ingathering of this waste material.

Equally interesting, but perhaps even less probable, is the suggestion of one noted scientific man to the effect that to barren and newborn worlds life may be brought by wandering meteorites. The objection to this lies largely in the fact that so far as we now know our meteorites are wholly of volcanic matter and not likely to contain life of any kind or in its simplest form.

That the meteorites that come to earth are directly connected with the periodic meteor showers there seems little doubt, but it is a singular fact that our most impressive falls do not occur contemporaneously with them. This is doubtless due to the small size of the individual in the shower, which astronomers say may be even smaller than a pea.

Of all the meteors that come into our atmosphere but a small portion survive to reach the earth, as I have already noted, and a still smaller number are found and preserved—not over three or

four a year. So far as we have information but two fell within the limits of the United States in 1924. I have made calculations based on reported weights and find that the total weight of all known falls, since records began to be kept, was but a little short of 200 tons. Those then who would have our earth built up of meteoric matter must, unless the rate of accumulation was vastly greater in the past, allow a very long time for its consummation, a period indeed running up into many billions of years.

Of course but a very small proportion of all the meteoric matter that comes to earth is ever found. But one fourth of the earth's surface is land, and only a portion of this so inhabited as to make finds probable, even were the falls seen. But about 250 have thus far been reported for the whole United States and portions of less than a thousand are preserved in all the museums of the world. There is seemingly no rule whatever for their distribution. Naturally a falling stone would be seen by more people in a thickly inhabited region, but if it fell on rocky soil or one covered with swampy lands or brush the chances would be against its actually being found. China is certainly densely enough populated and many falls have been reported, but there are no records of finds.

There seems to be something singularly elusive in the fall of a meteorite. It does not strike the ground where the observer thinks it is going to, but perhaps miles away. I have had occasion to notice this very many times. People will tell me they saw one fall and they send me a piece of it which usually proves not to be meteoric at all. One man sent me a stone that he was sure he saw fall and it was so hot he said it set fire to the grass. But what he sent me was a piece of quartzite belonging to a very ancient geological period that had been carried to the point where he found it frozen in the ice of the glacial epoch many thousands of years ago.

Robert Frost writes a poem about hunting meteorites. "Never tell me," he says, "that not one stone of all, that slip from heaven at night, and softly fall, has been picked up with stones to form a wall." And then he goes on: "From following walls I never lift my eye, except at night to places in the sky where showers of chartered meteors let fly."

I am afraid Mr. Frost is wasting his time. Searching for meteorites would be even more discouraging than that for the needle in a haystack, for in the latter case one supposedly has grounds for believing the needle to be there. But there is always the possibility. I know the case of a boy in a far-off state who found a queer-looking stone which proved to be meteoric. He then made a prolonged search and found several more which he sold for enough to give him quite a lift with his school expenses. I should state,

however, that these fell all at one time and the region was a dry one with little undergrowth to hide them.

As a rule meteorites, except in a dry climate, are of a very perishable nature. Not merely does the metallic part undergo a quick oxidation, but there is a minor constituent, one occurring in small, seemingly almost insignificant quantities, that makes much trouble. This is a compound of chlorine and iron which is peculiarly susceptible to oxidation, and begins "rusting," as we call it, almost immediately. Many meteoric irons are very quickly destroyed if left unprotected. For this reason probably no meteorites are found except on or near the immediate surface. If they fell in earlier times they have all been destroyed.

Of all instruments and instrumentalities for finding meteorites where not actually seen to fall the humble plow and its less humble holder have proved most fruitful. The expression "found while plowing" has become almost stereotyped through abundant repetition. In this way have been found a considerable number of the meteorites from the states of the lower Mississippi Valley. The reason is almost self-evident; it is one free from glacial drift, and the prevailing rocks of softer limestone, sandstone or shale. The plow strikes an obstruction which on examination is found to be of metal, or if of stone unlike anything in the neighborhood. Curiosity prompts the finder to take it to his home where perhaps it is put to some utilitarian purpose until some one comes along and recognizes it. Several large meteorites were found in Kansas some years ago by being struck by mowing machines and plows. It was a region of prairie soils, without stones of any kind. Hence they attracted the attention of the ranchers, who took them home and used them to hold down hay stacks and barrel covers until their true nature was discovered. In such cases the finder may himself suspect its nature and send it away for determination. I get a considerable number of such finds each year but am sorry to record that all too few prove to be meteoric.

The fascination of the study of meteorites is due in large part to the fact that they give us some clue to the nature and composition of other bodies in space. The telescope has taught us something of the size and shape of these bodies, the spectroscope something of their elemental composition, but in the fallen meteorite we can actually hold in our hand for examination and study a solid mass of rock that has come to us from unknown though outside sources. This was realized by the great naturalist Humboldt many years ago when he said: "There are only two avenues to our knowledge of the universe outside of us, one being light by the agency of which the motions of the heavenly bodies are revealed to us, while

the other consists in the masses of matter that come to our earth from the outer universe."

But what are these masses, you very likely will ask. I have already stated that they are in part of stone, in part of metal, but usually a mixture of the two. The metal is mainly iron with a smaller percentage of nickel and cobalt and traces of manganese, phosphorus, sulphur and platinum. The stony meteorites are interesting because they are all of an igneous and volcanic nature. No meteorite was ever found that consisted of limestone, marble, sandstone, shale, slate, schist or gneiss or any of the sedimentary or metamorphic types of rocks common to our earth and nothing in the nature of granite or of a fossil. They all belong to a very basic type which we call peridotite, pyroxenite or basalt and which from a geological standpoint are for the most part comparatively insignificant. And here is a very interesting and remarkable fact. So close is the resemblance between the meteorites and these terrestrial peridotites that an element found in one may safely be predicated in another though not in the same form. For instance, iron so abundant in meteorites in metallic form, though common in terrestrial rocks, rarely occurs other than as an oxide. This is on account of the abundant oxygen in our atmosphere and it teaches us that the meteorites were formed in a region where there was very little atmosphere. The world's supply of platinum and of diamonds comes from rocks of the peridotite group and traces of both have been found in meteorites. Truly, as the Frenchman Descartes wrote many years ago, "It is proper to infer that the earth and the heavens are made of one and the same matter."

HIGHWAY RESEARCH

By Professor S. S. STEINBERG

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GREAT as is our national prosperity, we have but few industries in which the total annual expenditure is more than a billion dollars. Authoritative estimates place the total expenditure for the construction and maintenance of roads and streets in the United States during 1924 as one and a half billion dollars, thus placing the highway industry in the select class of billion dollar enterprises. In view of this vast expenditure, scientific research, resulting in the more economical design, construction and maintenance of our highways, has great financial value in reducing the cost of highway transportation. When we consider that motor vehicles travel three hundred

million miles per day in the months of heaviest travel, that our annual consumption of gasoline is six hundred billion gallons and that our tire and accessory bill alone is eight hundred million dollars, we must realize that the economies that may be effected by the application of highway research result in an enormous saving both to the highway and to the vehicle owner. Experiments conducted in Iowa have shown that every dollar expended for gasoline on bad roads can be reduced to seventy cents on a good road.

One of the national agencies which is most active in stimulating highway research is the Highway Research Board of the National Research Council, of which Dean A. N. Johnson, of the University of Maryland, is chairman and Mr. C. M. Upham, state highway engineer of North Carolina, is director. This board recently held its fourth annual meeting at the National Academy of Sciences in Washington, D. C. At this meeting over three hundred representatives were present from state highway departments, universities and other organizations engaged in highway research, and much valuable information was presented regarding the economic factors pertaining to highway transportation.

A large proportion of the funds expended in the highway industry is appropriated to maintenance, as even the most scientifically constructed roads must be maintained. The continual stream of traffic passing over the highways of the country necessitates unremitting attention on the part of those to whom the highways are entrusted. For a number of years the necessity for constructing new roads and reconstructing old ones to keep pace with the enormous increase in automobile traffic shoved the matter of maintenance into the background, but in the last few years most of the states have been making intensive studies of their highway maintenance problems.

One problem that comes under the head of maintenance is snow removal. This illustrates anew the marvelous changes which have been wrought in our social and economic life by the development of the motor vehicle. Ten years ago the tremendous inconvenience and the enormous loss occasioned by blockaded highways after every heavy snowstorm were accepted by people generally with patient resignation. As the automobile, the motor bus and the motor truck came to be used in increasing numbers in moving passengers and supplies, the necessity for keeping highways open every day in the year became more and more apparent. Now in all the northern states the highway departments are removing snow on the country roads under their jurisdiction. Work of cleaning the snow on the through routes between the large cities usually begins before the snow stops falling. Most of the machines, such as tractors and

blade graders, which are used for maintenance during the summer, are called upon for snow removal in the winter.

Developments in highway traffic are so rapid that it is difficult to foretell accurately conditions over a very few years in the future. Using the available statistics for motor vehicle registration during the past years and studying its relation to the corresponding curve of population in the United States, Dean A. N. Johnson, of the University of Maryland, has reached the conclusion that there will probably be about thirty million motor vehicles on the highways in 1930. A similar study by Dean Johnson has shown that the average life of the motor vehicle is increasing from year to year. Thus the average life of an automobile bought in 1912 was about five years, whereas one bought in 1916 lasted about six and a half years. This increase in service may be attributed both to the better design of the vehicle and to the increase in the mileage of improved roads.

With the rapid development of motor vehicle transportation, need for new laws and regulations arose, and in the absence of definite information many of them were based on more or less scientific guesses. For instance, many laws regulating the maximum load that may be carried by trucks are based on total wheel load alone. They serve their purpose very well when the truck is not in motion, for a wheel at rest can exert no greater pressure than the actual weight upon it. Research conducted under the supervision of Mr. T. H. MacDonald, chief of the United States Bureau of Public Roads, has shown that the instant the wheel is set in motion a different condition develops. As the truck moves along a road, surface variation, tire roughness and other factors cause the wheels to mount vertically and on returning to the road make them capable of delivering impacts or blows equivalent to seven or eight times the actual wheel loads. In order to avoid these impacts and thus reduce the wear and tear on the motor vehicle and the highway, as well as the exhausting effect on the occupants of the vehicle, much attention is now being given by construction engineers to the degree of smoothness of the finished concrete. Instruments are being developed which will record the exact location of troublesome areas or obnoxious bumps. One state uses an apparatus which is attached to an automobile and which makes an automatic record of the deflection of the front spring. Another state uses a device mounted on sixteen wheels drawn by a truck which gives an accurate profile of the road. In order to obtain as smooth a highway surface as possible, the specifications in a number of states require that all inequalities of over one fourth inch, as shown by a ten-foot straight edge on the finished concrete pavement, must be removed.

Consideration of the gasoline tax is of special interest to the motor vehicle operator. Thirty-five states now have this form of tax, the rates ranging from one cent to three cents, with the exception of one state, which has a four-cent tax. A one-cent gasoline tax increases the cost of operating the average vehicle by one tenth of a cent per mile. On a trip from Washington to Philadelphia the tax would amount to ten cents. The trip over the Lincoln Highway from New York to San Francisco would be taxed $2.50. The motorist or truck operator is assured of a good return from the taxes he pays, since the receipts are very largely devoted to road construction and maintenance. In 1923 four fifths of the motor vehicle license revenues and more than one half of the gasoline taxes were turned over to the state highway departments for expenditure under their supervision, and a considerable portion of the remainder was expended by the counties for road purposes.

The problem of highway finance resolves itself largely into a question of the just distribution between the burden on land, or real property, and the burden on the highway user. It seems only fair that the highway user, whose demand for service is largely responsible for highway improvements, should assume an equitable share of the burden in the form of motor vehicle and gasoline taxation.

In the United States there are about three million miles of all types of roads. Of this amount about 15 per cent. are improved with some kind of surfacing and nearly all this improvement has been made within the last ten years. The mileage of the so-called earth roads, without any surface improvements, is therefore about eighty-five per cent. of the total, or two and a half million miles. In view of this enormous mileage of local roads, highway engineers are seeking a new type of surface that will serve for secondary traffic and yet be low in first cost and maintenance. Because of the small amount of traffic on the local roads, the construction of expensive surfaces, such as concrete, asphalt and brick, are not economically justified. Highways surfaced with gravel will carry five hundred to six hundred vehicles daily, but begin to show ruts when that number is exceeded. The Highway Research Board hopes that research will find a surface that will carry up to two thousand vehicles a day and will be intermediate in cost between the gravel road at $8,000 a mile and the concrete road at $35,000 a mile.

The need is felt for some method of stabilizing earth roads, particularly in wet weather, so that the local farm roads may be made to withstand the increasing demands of traffic upon them. Whether this be brought about by X-ray treatment of the soil, removal of those invisible but tangible particles known as colloids, or by heat

treatment of the earth, or by other means, is for research to determine.

In his travels, the average motorist would rather meet with an accident than with a detour. This may be due to the feeling that before he is through he may be faced with both. Highway engineers, realizing the worries incident to detouring, as well as the wear on the vehicle and the loss in time occasioned by it, are anxiously awaiting the result of researches being conducted with a view to accelerating the curing or setting period required for concrete.

This, the greatest era of prosperity in the United States, is in no small measure due to our system of highway transportation. To insure its continuance, highway engineers, enlightened by highway research, definitely commit themselves.

COMMUNISM AMONG INSECTS

By THOMAS E. SNYDER

U. S. DEPARTMENT OF AGRICULTURE

MAN'S civilization is higher than that of insect communists: man is developing, while they are standing still. Can we not build our houses so as to keep out these most undesirable citizens? In the world war of man against insects, although greatly outnumbered, man's intelligence will eventually win the battle against insect vandals.

PREHISTORIC CIVILIZATIONS

Civilization ever has been the pride of man! However, certain insects had established civilizations and social systems before the evolution of man; these civilizations of insects are geologically much older than either man himself or his boasted civilization. The "social insects" include the bees, wasps, ants and termites (or "white ants") which live in colonies, have a well-defined caste system and closely adhered-to division of labor.

THE TERMITES

The termites or "white ants" are typical of these social insects, since they display an elaborate society or communism in an old or primitive form of life, paralleling the society of the more highly specialized true ants. For termites, although ant-like in appearance, are not true ants, but a much lower form of life; they are most closely related to the cockroaches, which are, geologically, very ancient insects. Unlike the ants, termites are not terrestrial, dominant insects; they are pale in color, blind, soft-bodied and usually subterranean or, at least, secluded in habitat. They have been forced to "dig in" in order to survive, but have, in consequence, "underrun" tropical countries.

There are a few exceptions, where the termites are harvesting in habit and come above ground into the sunlight; these forms, however, are dark colored and have eyes. Normally, termites are forced to construct earth-like "shelter tubes," whenever they come above ground in search of food or water; often these tubes run up on the trunks of trees to great heights, especially on cocoanut trees in the tropics.

Ants, being terrestrial and aggressive, use their jaws, sting and formic acid spray as weapons of offense as well as for defense.

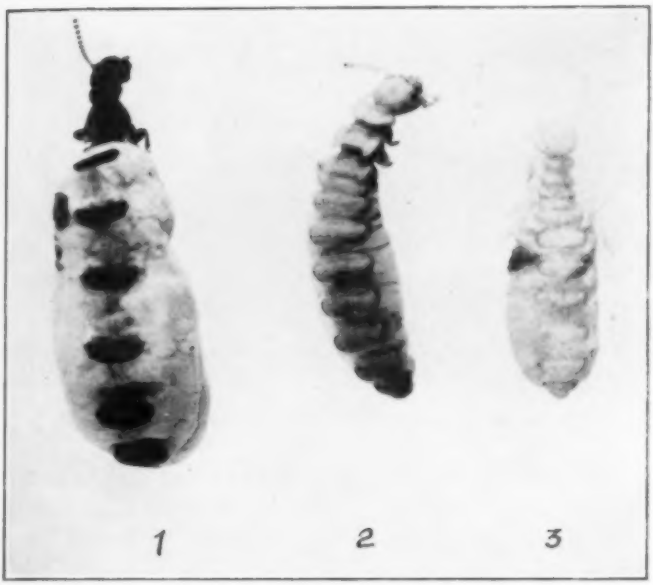


FIG. 1. THREE TYPES OF EGG-LAYING TERMITE QUEENS FOUND IN THE UNITED STATES

1, the deälated winged form; 2, the form with short wing pads; 3, the wingless form. It is useless to search for and destroy the queen; hundreds develop to take her place.

Termites have all their weapons located on the head and the jaws and repugnant frontal gland secretions are used merely for defense.

Termites are fewer in number than ants, only about fifteen hundred species, at present, being known. They are widely distributed throughout the temperate to the tropical regions of the

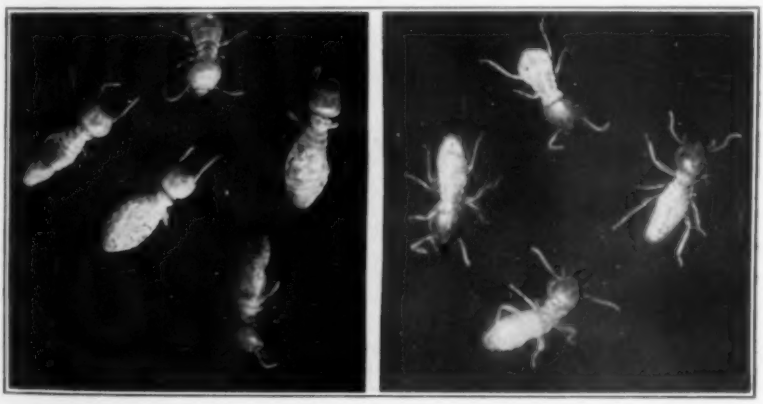


FIG. 2. Worker termites on the left; Soldier termites on the right. (Panama.)

FIG. 3. HIGH MOUND NESTS OF TERMITES IN PANAMA

world, but reach the height of their development and abundance in the tropics. There are forty species in the United States, distributed from Maine (even from Ontario, Canada) to Florida; through the Central West, south of the Great Lakes; in the Rocky Mountain region and on the Pacific Coast.

THE CASTE SYSTEM

Colonies of termites consist of "kings and queens"—the parent reproductive adults—"workers" and "soldiers," all of several types, of diverse and often very odd forms. The ancestral termite was represented by a single winged form (males and females),

FIG. 4. A CITY OF THESE MOUNDS ON THE SAVANNAH, IN PANAMA
(Photos 3 and 4 by J. Zetek.)

which mated and reared other sexual males and females. Gradually, through the ages, after gregarious life, colony life developed and other forms or castes have appeared.

Some of these forms are other types of sexual adults, with short wing pads or entirely wingless; others are sterile workers and soldiers, incapable of reproduction, but especially fitted for certain duties in colony life.

The workers care for and feed the young, the reproductive forms and the soldiers; the soldiers defend the colony when invaded by the greatest enemy of termites, the true ants. For this rôle of defense, saw-toothed jaws or mandibles were utilized by the most primitive termites. Later, a special gland on the front of the head, which exudes a sticky secretion, developed and superseded the mandibles.

Among the termites intermediate between the primitive and highly specialized forms, both mandibles and frontal gland function. This pungent secretion, which exudes either from an opening, a short tube or an elongate beak, is more effective against ants than are jaws. These gland-bearing termites, when in contact with ants, thoroughly gum them up, so that they are rendered helpless.

In other highly specialized termites, the jaws are markedly asymmetrical or very slender, elongate or twisted. Jaws of the latter type could not possibly be used for biting, but they are made use of by bringing together and flipping or snapping particles of earth at the invaders; or even flipping away the invaders themselves.

There has been progressive development, not only in the jaws and frontal gland of the soldier, but in the legs, wings and defensive armor or spines on various parts of the body of the other castes. The more highly specialized termites have lost the strong power of flight possessed by the more primitive forms.

The most primitive termites have no workers, the only sterile caste being the soldier. Whereas, more specialized termites may have two types of workers and three types of soldiers. On the other hand, among one group of the higher termites, the soldier caste is entirely lacking. Some termites live in the nests of others, where they are afforded protection; the termites with no soldiers sometimes are closely associated with termites that have "soldiers."

The Colonies or Nests

The colonies or nests of termites are constructed of earth or earth-like material, in the ground, in low or tall mounds on the ground, in carton tree nests, or within wood. They far antedated the "adobe" houses of man, his use of pressed dirt for foundations and walls of buildings and of wood for shelter. Often whole vil-

FIG. 5. A "NIGGERHEAD"
Carton termite nest in a tree. (Panama.)

lages or cities of termite nests dot the plains or prairies, as do the huts of the aborigines. These nests are hard, oriented with reference to the sun's rays and afford protection from both animal life and the elements. Termite nests in the tropics of Africa attain a high type of architectural perfection and are so constructed, utilizing shingle or ledge-like processes, as to shed rainfall—often torrential in these regions—yet at the same time permit free ventilation.

Within these nests there is an orderly and systematic arrangement of cells and galleries to house the large number of inmates. There is a special cell or "royal chamber" in which the parent reproductive forms, normally a single pair, are practically imprisoned. This chamber is usually in the most protected and inaccessible portion of the nest. From this cell galleries run to favorably located "nurseries," to which the young or nymphs are carried by the workers, for feeding, care and more rapid development in the warmer portions of the nest. These galleries, however, will not permit the passage of the old queen. She is merely a huge, highly developed, immobile and imprisoned egg-laying machine, fed and tended by the workers.

During her youth, she and her male consort struggled hard to establish a home and feed and rear the first brood of young. Later, with care and feeding by her young she grows to a proportionately enormous size, reaches the dowager stage and is more or less helpless. She loses the power to move about, the jaw muscles degenerate and she is fed by workers on an especially prepared rich diet. With the king she may live as long as twenty-five years.

If the queen dies or is lost, the old king will forego his former meritorious monogamous life and consort with a harem of young queens, with short wing pads, veritable insect "flappers." When both the queen and king die, large numbers of young queens with short wing pads and a fewer number of similar kings will replace them.

Hence, it will be seen that the termite colony is not a "feminist" society, as is the case with the bees and ants. Even with communism, there are "equal rights" for both sexes! Even the workers and soldiers are of both sexes, although they are sterile!

Other galleries lead to "fungus gardens," wherein peculiar, edible mushrooms are grown by the termites. There are exits and

FIG. 6. SECTION THROUGH TERMITE NEST TO SHOW "FUNGUS GARDENS"

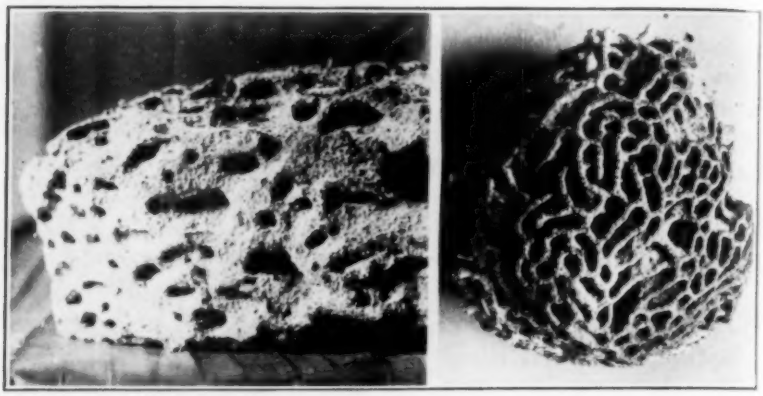


FIG. 7. TWO TYPES OF COMB FROM FUNGUS GARDENS
Showing the "cauliflower"-like fungus growth as bright, white granular bodies.

entrances well guarded by the fearsome-appearing, large-jawed soldiers.

In nests of other types, there are storage rooms for vegetation, harvested and brought into the nest by large files of foraging workers, with their ranks closely guarded by the soldiers.

Some termite nests are entirely within the wood of trees, logs or stumps; this wood serves as both food and shelter. The nests made in the wood are similar to those constructed in earth. The chief food of most termites is cellulose, which they obtain from living or dead wood and other vegetation. To digest this cellulose termites have within their intestines thousands of protozoa—low forms of life—which serve as enzymes.

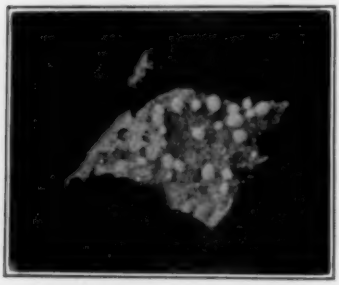


FIG. 8. CLOSER VIEW OF THE CAULIFLOWERS. (Java.)
(Figs. 6, 7 and 8 photographed by D. Fairchild.)

FIG. 9. A PROTECTED INSECT GUEST OF TERMITES
Which lives with the termites in a mutually beneficial rôle; the termites obtain exudate from the guest, the guest food from the termites. (After Silvestri.)

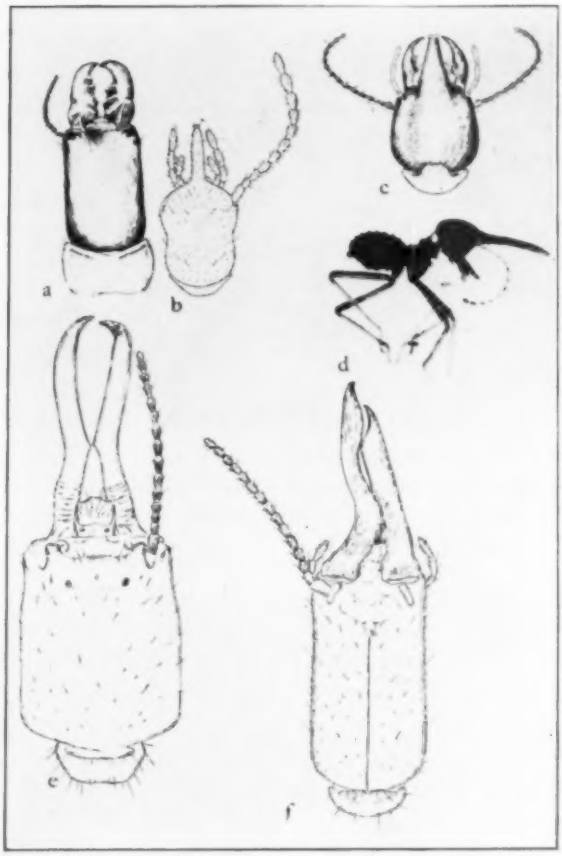


FIG. 10. HEADS OF CONTRASTING TYPES OF TERMITE SOLDIERS
(a) Soldier with saw-toothed jaws; (b) soldier with a beak which secretes a repulsing liquid; (c) soldier with a combination of jaws and beak; (d) full view of such a soldier; (e) and (f) soldiers with elongate or twisted jaws used defensively in flipping dirt.

These peculiar, odd-shaped protozoa are found only in the bodies of termites—nowhere else in nature. Termites whose food is not cellulose, but mushrooms or other special diets, obtained from the "workers" or protected "insects guests," do not contain protozoa. These guests of termites are degenerate but highly specialized forms which serve as "ant cows."

Occasionally termites vary their vegetable diet with a meal on a feeble or disabled fellow-communist. All their instincts of care and feeding of young are based on selfish impulses. They obtain body secretions or exudate in return!

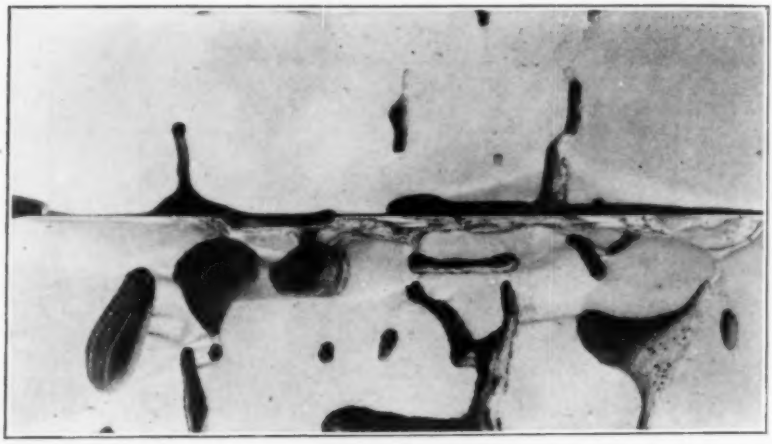


FIG. 11. DAMAGE BY TERMITES
Damage to reels of imported French cigarette paper stored in a factory at New Orleans, La.

COMMUNISM AND ITS LIMITATIONS

Nevertheless, while man and his civilization are comparatively young and there have been ebbs and flows in development, there has been consistent, if not continued, progress. Termites, on the other hand, after having reached certain states of body and community development, have made no further progress. Of course termites, as well as other insects, can not reason and are merely guided by hereditary instincts and tropisms—hunger, sex and fear being the principal impulses. Their progress was by evolutionary development, as was man's, but man, with reasoning powers and individual initiative, has been able to surpass all other forms of animal life. Granting this, man will lose his birthright of freedom if he ever submits to the limitations of communism. Let him "go to the ant or termite" and take heed! Russia has both types of insects within her vast domain!

THE SWARM

Interest is always attracted by unusual flights of any form of animal life, whether birds or the less conspicuous insects. In the tropics, especially, there is almost an element of magic attendant upon a termite "swarm." After a rain, apertures are opened in the ground or "ant mounds," and suddenly the air is alive with fluttering, winged hordes, which emerge from these exits. After this flight, which may last for several hours, the holes are closed from within by the workers and all trace of life disappears, even as suddenly as it had appeared.

This is the annual colonizing flight of the sexual adults; these are impelled to swarm to establish new colonies. It is not a "nuptial flight," as is the case with bees and ants. Only after losing their wings do males and females mate and form new homes in wood or in the earth. When this flight occurs in a building in the United States, it should serve as a danger signal to the householder that the woodwork of the buildings is infested by termites. Such swarms occur at least once each year, in the spring or autumn.

Economic Importance of Termite Communists

Like other communists, termites have a great facility for destroying the property belonging to others. They do millions of dollars worth of damage annually. Such damage is greatest in the tropics, but even in temperate regions, their ravages entail losses of thousands of dollars. With the felling and clearing of forested land, termites attack the buildings, crops and other works of man. Serious damage is done to any untreated timber which is in contact with the ground, such as telephone poles, wooden bridges, windmill

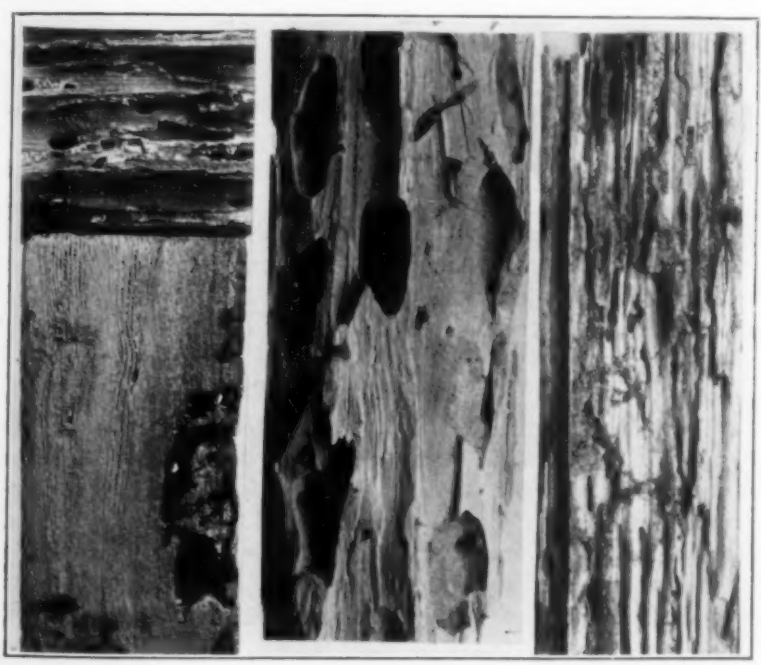


Fig. 12. Damage by termites

On the left, California redwood beams, in a building on the Pacific Coast, eaten through by termites native to the United States. In the center, cottonwood beam, in "adobe" house in Arizona, burrowed by termites. On the right, pine flooring, in Iowa, honeycombed by termites.

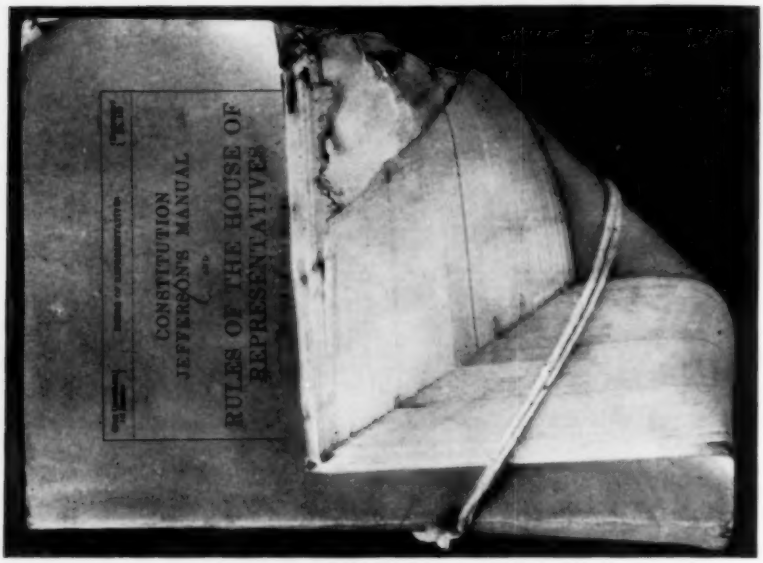


FIG. 13. BOOK RUINED BY TERMITES AT WASHINGTON, D. C.
Communists destroy books, especially those dealing with law and order.

towers, silos, fencing, and all types of buildings. Forest, shade and fruit trees, as well as living crops, are injured.

Perhaps the most serious losses in the United States are caused by termites to the woodwork of buildings and material stored therein. Such damage could be very easily prevented by slight modifications of city-building regulations; untreated wood must be insulated from contact with the ground. Keep timber, political and wooden, away from dirt!

REGULATIONS AND CONTROL

The United States Department of Agriculture receives many requests each year as to how to get rid of these "flying ants" or termites in buildings. Most of this damage is due to improper construction. Termites enter the woodwork of the buildings because, somewhere, there is untreated wood in contact with the ground.

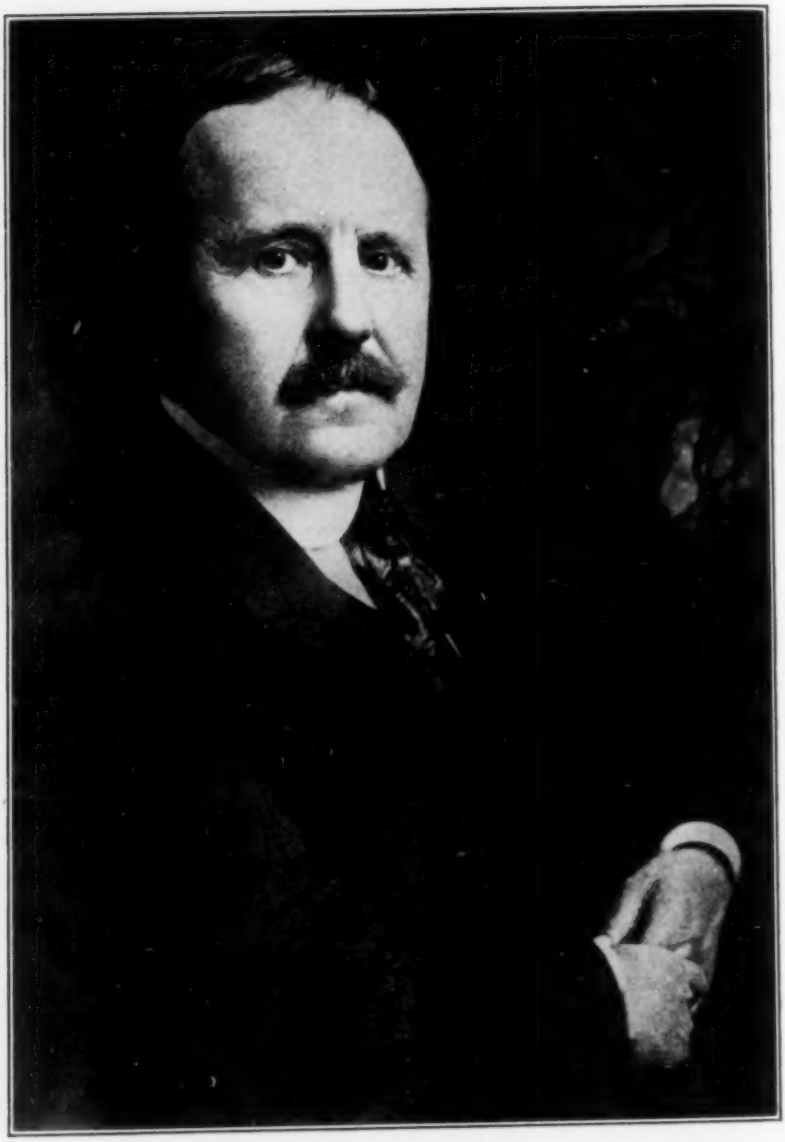
Recently, the Department of Agriculture has been advocating a few slight modifications of the building regulations of various cities, in efforts to prevent attack by these insects. These rules are: No untreated wood should be laid on or in the earth, and untreated beams should have at least an inch of concrete between them and the earth. Where it is desired to put wood in direct contact with the earth, it should first be impregnated with coal tar creosote. If

FIG. 14. BASEBALL BAT DAMAGED BY TERMITES AT WASHINGTON, D. C.

this is not practical, there should be foundations of concrete or stone. No lime mortar should be used in brick work in foundations of buildings, since termites are able to penetrate lime mortar after a few years' service. Such brick work, either on or extending below the surface of the ground, should be faced and capped with concrete at least one inch thick.

Termites are not like ants, which can be killed by insecticides or fumigation; they must be prevented from getting into the building from the ground, through their hidden burrows in untreated woodwork.

It is a great hardship for a householder, on a moderate salary, to be forced to spend several hundred dollars a few years after purchasing a building because of damage by termites. The fault is in the construction, and the building regulations should be such as to avoid this damage, so that the householder should not have to pay. By insisting on complete insulation of all untreated woodwork from the ground, insurance against attack by termites can be secured.



WILLIAM ALBERT LOCY

WILLIAM ALBERT LOCY

ZOOLOGIST AND HISTORIAN OF BIOLOGICAL SCIENCE

By Professor C. E. THARALDSEN

NORTHWESTERN UNIVERSITY

WILLIAM A. LOCY was a man who was distinguished alike for the diversity and importance of his original contributions to knowledge, his historical work and his influence on men of science as well as the laymen: one whose supreme gift was the ability to see with an intelligent and interpretive mind and whose published observations reflect this quality in their high level of scientific achievement. His death, October 9, 1924, terminated a long and rich career of noble and unflagging devotion to science which secured a harvest of abundance. It is an honor to the various learned societies to have numbered Dr. Locy among their members. It is an honor to Northwestern University to have felt his influence for so many years. We here express our reverence for the man, and our admiration for the scholar. It remains our part to keep alive the tradition of truth-loving, of scientific devotion and of perfect modesty which is our legacy from W. A. Locy.

A descendant of Dutch ancestors who emigrated from Holland in 1651, William A. Locy was born in Troy, Michigan, in 1857. Graduated from the University of Michigan in 1881, he remained with his Alma Mater one year as a graduate student in zoology, receiving his master's degree from that institution in 1884. He pursued advanced work at Harvard in 1884 and 1885, holding a fellowship under Mark. The year 1891 was spent at the University of Berlin. In 1894 he was awarded an honorary fellowship at the University of Chicago, where under Whitman in 1895 he received his doctorate. He also spent several summers at the Marine Biological Stations on both the east and the west coasts as well as one season at the Naples station. In 1906 he was awarded the honorary degree of doctor of science from his Alma Mater, the University of Michigan.

Besides being a member of the honorary and scientific fraternities of Phi Beta Kappa and Sigma Xi, Dr. Locy was an active member of the American Anatomical Association, the American Society of Naturalists, the American Zoological Society, of which he was president in 1915, the American Association for the Advancement of Science, the History of Science Section of the American Associa-

tion for the Advancement of Science, of which he was one of the founders and its first vice-president, the Microscopical Society of Illinois and the Illinois Academy of Science.

After four years of apprentice work in secondary schools, Dr. Locy entered upon his academic career in 1887 when he accepted the professorship of biology and later of animal morphology at Lake Forest University, a position he held for eight years. In 1896 he succeeded Professor E. G. Conklin as director of the Zoological Laboratories of Northwestern University and continued there as an active teacher and producer up to the day of his death—a period of twenty-eight years. During his life, Dr. Locy produced fifty-six papers—several of which were landmarks in their respective fields. Three books, all on the history of biology, also were credited to his pen, the last of which was sent to the publishers but a few days before his death. During his connection with Northwestern University, fifty-four advanced degrees were awarded to research students doing work under his supervision.

A mere enumeration of cold facts does not give us a complete conception of Locy, the man, the teacher, the zoologist and the historian. Conklin said, "I honored him for his unselfish devotion to his chosen work and his loyalty to his associates." His manner was courteous, his spirit gentle, his tastes simple. He lived the life of a scholar whose highest ambition was to know the truth and make it known to others. He possessed a strong and upright personality of Spartan simplicity and was an untiring man of science to whom work was a pleasure of creative power. Sincerity, accuracy and transparent honesty characterized all his deeds. He had the courage of his convictions and the independence of one who had early learned to think and investigate for himself; his good sense exerted a most wholesome influence on educational theory and practice; his cheerful and straightforward friendliness endeared him to all who knew him. There was little self-seeking in his nature. He was unselfish and sincere with all men, blessed with a broad charity that was not critical of small things. He sought no positions of honor, but faithfully discharged every duty that was his to perform.

He was not a recluse, but kept in energetic touch with the social and intellectual life of the community, nor could he be comprehended in the scientist or the educator, for he enjoyed enviable intimacy with fine letters in both verse and prose. He was abreast of current events, a student of art and a lover of music. Above all he was not a nihilist, but a constructive philosopher, who going from effect to cause found real rest for his philosophical faith in a primal cause.

In scanning his life it would seem as though he had been inspired to fulfil a mission of diversified good, for his major achievements fall into three distinct fields of endeavor, that of teacher, zoologist and historian.

Locy took up his life occupation of teaching with other preparation than that of the patient student and promising scholar, in that he put into it the power of a great personality which helped to inspire and determine the life ideals of many young men who came into contact with him. Perhaps his greatest delight and satisfaction was in his work which brought him into immediate relation with active and earnest students, many of whom are already reflecting credit upon the profession whose testimonials assign their inspiration with affectionate veneration to this master teacher.

Dr. Locy was interesting as a lecturer and knew how to arouse enthusiasm and to inspire the student to independent thought. He had the faculty of clear and forceful statement, being logical rather than rhetorical, convincing rather than persuasive.

He had a catholic spirit that sought the truth in everything and rejoiced in finding and was always enthusiastic for any genuine effort to extend the borders of human knowledge. His scholarship was comprehensive, accurate and exacting. Although he spent much time with his advanced students and his own researches, he never neglected the elementary student, but religiously held to the idea that the course in general zoology was most fundamental, as here the foundations are established for future inspiration and work. Under his direction, this course grew in popularity and became one of the largest classes in the university from which more than the average number of students followed up the general course with more advanced work.

Locy always emphasized the importance of what might be termed old-fashioned zoology. He held that in the complicated maze of specialization in the various modern branches of the subject the student was apt to lose perspective of the field as a whole and that the foundations of all zoological knowledge could only be established through a thorough training in comparative morphology. It was always his purpose to systematize the development of zoology and present it as a harmonious whole by bringing out and correlating the salient features that have been established through the course of this development. Comparative morphology, therefore, formed the background of the zoological curriculum, a thorough training on which he insisted before permitting the student to pursue more special branches.

He was a pioneer in this country in utilizing the method now widely recognized of presenting the zoological courses on a historical

background, emphasizing the fact that we know most vividly that which we know in its origins. Throughout his twenty-eight years at Northwestern this was always an integral part of his courses, and he wrote articles urging the modification of our pedagogy to include the teaching of science in its evolution as a more successful educational method.

His scientific papers and addresses from the very first showed his enthusiastic interest in scientific work and his love and appreciation of zoological research. He was always hospitable to newly discovered truths and thus continued to be a student and investigator to the end of his days. Without a doubt, his researches, although many, would have been greater if confined to narrower lines, but I am inclined to think that he was the better teacher because of the wider range of his field. Sincerity, accuracy and honesty characterized all his work. Those who had the opportunity to know his papers collectively know how strikingly manifest was his devotion to the furtherance of zoological knowledge. His writings everywhere reflect the spirit of a leader of thought. His scientific contributions evidence great power of observation, extreme care and active scientific imagination, as well as a strong sense of the fundamental. He therefore engaged in no petty researches and the few that he published included several landmarks in their respective fields.

Locy's first paper of consequence was on the embryology of the spider. Here he made the first comprehensive attempt at an analysis of its early embryological development. To this day, this work stands as one of the two authorities on this subject. He was also the first to explain substantially the development of the spider eye.

Following this work came a series of twelve papers, embryological and neurological in character, dealing with the brain, special sense organs and cranial nerves of vertebrates. His studies of the embryonic neuromeres of the fore- and mid-brain of fishes stand in the forefront of investigation on neural metamerism and in the center of the controversy that still continues on this subject. His observations on the accessory optic vesicles in the chick embryo threw new light on transitory organs of the neural tube and gave support to the hypothesis that the vertebrate eyes are segmental. His studies of the nervus terminalis in elasmobranchs, while not contributing an entirely original discovery of this addition to the classical roster of cranial nerves, was nevertheless contributed so early and was so thorough as to dominate and become the standard of all later investigations. In his investigations on the fifth and sixth aortic arches in birds and mammals, Locy settled the discussion as to the existence of the sixth aortic arch and identified defi-

nitely the origin of the pulmonary artery. Through investigations of the embryology of the bird lung, he clarified the recognized morphological inadequacy and incomplete knowledge on this important organ.

For a man whose major time was devoted to teaching, he contributed in unusual measure toward zoological research and to the history of biological science.

Reminiscing over his student days when zoology was in its infancy, Locy made the statement that zoology was purely descriptive. He said:

> I craved for a broader view of the salient features of biological progress to see what it was all about. I asked for bread and they gave me stones. Nothing but my own deep-seated interest in natural history impelled me on to the point where I was able to gain that perspective for myself. It was this experience which made me realize the importance of the historical aspect of the science, and it was here that I conceived the idea and developed the ambition to be able some day to develop an account of the rise and progress of biological thought.

Although his first published papers on the history of biology did not appear until later in his life, this phase of his activity has undoubtedly become his most noteworthy achievement and that by which he will be remembered longest. All his life he had been a student of history, but this interest was first developed into tangible form when under the influence of Whitman, in 1894–95, he was encouraged to give it serious attention. This interest resulted in his first historical paper in 1901 on Malpighi, Swammerdam and Leeuwenhoek, a paper which received very enthusiastic reception. From this time on, two different interests are clearly marked in Locy's work; one, the detailed morphological investigations in the laboratory; the other, the historical researches into the musty volumes of the past. At first the former held the balance of his interest, but gradually as time went on his historical researches focussed his attention. The productive period of his life may be divided roughly into two periods: the first from 1884 to 1901, dominated by his detailed morphological researches, and the second from 1901 to 1924, characterized by his historical work on the rise of biology.

The historical phase of Locy's interest covers three lines of endeavor. First of these was his individual papers published on certain definite periods, topics and men of biological importance; the second was his three books on the history of biology and zoology, covering the field in general; and the third was characterized by his efforts to promote interest in research on the history of science and its importance as an educational need.

Individual papers on special phases of the history of zoology and biology, such as "Malpighi, Swammerdam and Leeuwenhoek," "Von Baer, and the rise of embryology," and "Anatomical illustrations before Vesalius" were clear-cut, scientific analyses of facts gleaned from the original sources which cleared up and brought under a common point of view many disputed points.

In 1908, he made his first attempt to bring together the broader features of biological progress by the publication of "Biology and Its Makers." This volume has perhaps been more widely read than most historic-scientific books. It is an untechnical account of the rise and progress of biology written around the lives of its great leaders. It represents the first comprehensive attempt in America to correlate, condense and popularize the various branches of biology. It is inevitable that biologists in special fields should find many imperfections in such a general work, but the chief purpose of the author to indicate the sources of biological ideas and the main currents along which they have advanced was accomplished in an admirable manner and the work has created an epoch in the advancement of biological history. It has filled the gap which he himself felt during his college days, and from my own experience, I know that it has been the direct inspirational cause that has induced many a young man to enter the field of zoological research as a life work. To the layman it has given a readable and much needed humanizing account of the important part that biology has played in intellectual progress.

Ten years later followed a more condensed volume entitled "The Main Currents of Zoology." As the title indicates, this is a historical treatise confined entirely to the field of zoology. Here Locy pictures the broader developmental features of zoology as a unified science and not merely as accretions of knowledge concerning animals. He draws a vivid picture of its importance as a subject of general education and also outlines the outstanding biological advances of the nineteenth century.

The effect that these two books have had on the teaching of zoology as well as being general cultural contributions can not be overestimated. Aside from the fact that Dr. Locy was a pioneer in this field in America, it is interesting to note that the general zoology, botany and biology text-books everywhere have adopted the historical method of presentation to a greater or less degree since the publication of these volumes, and a number of them have made direct use of the material which was made available by his work.

During the last few years of his life Dr. Locy had been conducting extensive researches with the view of building up a com-

prehensive survey of the growth of our knowledge of all organic nature from the earliest foundations down to the present time. This contribution was intended to be a two-volume treatise, but the author lived only to complete the first volume which was sent to the publishers shortly before his death. Although this volume is complete in itself and will be a monumental contribution befitting this great man, the scientific world has lost much through his untimely death.

His efforts directed towards the promotion of research in the history of science in general are nowhere better illustrated than in the organization of this society of eminent men whose primary aim is the cause he so valiantly championed. He was one of the members of the committee appointed by the permanent secretary of the American Association relative to the History of Science Section. The results achieved by this committee were to a great extent the efforts of Professor Locy and it was through his efforts that the policy and organization of this section was largely determined. He always took an active part on programs and committees. His efforts were recognized in that he was elected its first vice-president. His loyalty and devotion to the history of science movement to create an independent section was not rewarded during his lifetime.

At this close range there is difficulty as well as danger in attempting to define Locy's position in the history of the development of science. The history of science is an attempt to clarify man's relationship to nature as contrasted with the philosophical history which deals with the ultimate reality. During the middle ages science was a part of theology. Theologians defined scientific thought in the interest of a supernatural interpretation of the universe. The progress of science was parallel with a continuous movement to secularize it, to make it the property of the layman and to remove it from the bonds of prejudicial interpretation. Locy's historical contributions have been a record of the part that the biologists played in this movement. Of all phases of this intellectual transition, science undoubtedly has been the greatest secularizing agency. Among the sciences, biology probably played the foremost rôle, for it was more closely connected with man's social evolution, and the biological principle of evolution contributed as much as any other factor in bringing about the radical changes of thought with regard to man's relation to the universe. Locy's contributions therefore cut through the very essence of European thought during this period. Within the last decade, there has not been a general history produced which does not devote at least a chapter to the history of science and the part it has played in in-

tellectual and social progress. In this connection we find the contributions of W. A. Locy always mentioned as among the foremost biological sources.

Most historians do not have the scientific training to evaluate scientific facts, and most scientists lack the historical perspective to comprehend the relation of the development of scientific thought to the general intellectual development. Locy seemed to possess both qualities and as a pioneer in the biological phase of this movement in America he has contributed much. The fact that his contributions were translated into the German would indicate that his work was not local in influence.

Locy's contribution to the development of the history of biological sciences, depicting the struggle and final triumph of this important branch of scientific thought, is only a part of the larger story of human progress in general; yet it is an important part and represents an earnest attempt on the part of a man of science to seek out the broader avenues of intellectual development in the biological field and to make them known to others. The results of his own labors are the most fitting monument that can be erected to his memory.

NEW LIGHT ON THE PHYSICAL DATA OF LANGUAGE

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Egocentric Conceptions in Science

The advancement of science may be defined as the progressive enfranchisement of the human mind from the tyranny of an egocentric consciousness. The royal prerogative of the spirit to hold itself superior to the phenomena of matter is undoubtedly necessary to a well-ordered intellectual "state of man"; but successive delimitations of the exercise of the prerogative have proved indispensable to the efficient coordination of those functions of mind which determine the immediate and practical knowledge that we call science.

Astronomy made little progress until once for all it shook off the tyranny of astrology and abandoned the belief that the movements of the heavenly bodies were "secret influences" commenting upon human activities. So with chemistry when it gave over alchemy and efforts to discover a means of transmuting gross and ignoble substances into the "noble metal" of gold. These enfranchisements were violent and revolutionary. That of physics has been more gradual and apparently is not yet quite complete. A few physicists still seem to expect the discovery of a source of energy that will redeem man from the first curse which makes him unhappy in this vale of tears, and one of them has even provided for him when he leaves it a Valhalla which he may enter without the trouble of being "born again."

While such vagaries of individuals are not, of course, chargeable to the subject itself, they nevertheless show how easy it is to frame a twentieth-century knowledge of physical phenomena in the egocentric categories of the Renaissance. And it is especially easy for the college student of physics to do this because much of his cultural training involves egocentric categories, and many subtle confusions between what is physical and what is psychological still cling to the skirts of physical theory.

The phenomena of light, thanks largely to spectroscopy and photography, and consequent connections with chemistry, are now analyzable into mathematical relations more or less independent of visual sensation. The phenomena of electricity, owing to their intimate connection with the chemistry of matter and to the fact

that they have few obvious relations to cardinal modes of sensation, are comparatively free from psychological distinctions, and our knowledge of them, such as it is, is almost wholly mathematical.

Their Prevalence in Acoustics

But our fundamental definitions of sound are still largely psychological and egocentric, and our fundamental categories for its phenomena, *viz.*, "pitch," "loudness" and "quality," are essentially psychological distinctions, each of them being a tacit reference to certain reactions of the human nervous system as they affect auditory sensation.

While this fact has not invalidated the work of the physicist, it has forced upon him the more or less unnecessary burden of familiarizing himself with data which are not physical but psychological. It is significant that much of the essential progress in the field of acoustics has been due to physicists who have been familiar with the development of music, and that the field of speech sound, of whose development the physicist as a rule knows little, has until recently received almost no illumination from physical investigations.

Their Effect upon the Study of Language

Moreover, this confusion between physics and psychology is largely responsible for the crude and erroneous egocentric conceptions of language which beset our cultural education and render nugatory most of our practical training in this important function of consciousness.

The physicist is often really thinking psychology when he thinks he is thinking physics, and the psychologist is often thinking physics (and that, too, of a somewhat amateur brand) when he thinks he is thinking psychology. And when the mere philologist, who must needs make love to the assistance of both these gentlemen, seeks the whys and wherefores of the speech-sound phenomena with which he must deal as recorded facts, he is buffeted back and forth between psycho-physics and physico-psychology to no purpose but the irritation of all parties concerned.

The reason for these conditions lies in the fact that until recently experimentation in this field has been largely dependent upon the human ear for a means of recording and analyzing the phenomena in question.

Recent Progress in the Technique of Sound Measurement

But the past ten years has seen the development of sound-measuring mechanisms that are much more delicate than the human

ear and are more or less independent of its limitations. Take, for instance, the phenomena of so-called "beat tones." It is a well-known fact that when two air-wave trains, each producing the effect of a tone, combine under certain circumstances, three tones are heard, the two corresponding to the two air-wave trains and a third which is different from each. Professor D. C. Miller with his Phonodeik has shown experimentally that this beat-tone has no physical existence, but is a ghostly creation of the auditory mechanism, a psychological hallucination common to all normal minds and having much to do with our appreciation of music.

Much of this recent progress has been due to telephony and the transmission of speech and musical sound by radio, mechanical operations which have made these questions matters of practical engineering.

We are thus upon the edge of a new development of physical science which is of vast consequence to the science of language.

One of the first fruits of these new investigations will undoubtedly be a new phonetics built upon definite physical data to take the place of the ancient speculative system founded upon data which are uncertain and arbitrary. It is the chief purpose of this paper to forecast the development of this new system along the lines which recent physical investigations into the nature of speech sound are already fast determining.

The Arbitrary Categories of Medieval Phonetics

Attempts to determine the constants of speech sound are by no means new. The Romans of the classical period were more concerned with the rhetorical applications of language than they were with its essential nature. Like many of us moderns, they took speech for granted and skill in its use as a more or less divine gift, and displayed little curiosity about the nature of its phenomena. Cicero, for example, observing that the Latin of his day is surprisingly constant in respect to vowel length and pitch distinctions, "even among the unlearned who know nothing of grammar," concludes that these things are *communibus infixa sensibus*, and uses the fact as evidence of intuitive perceptions mysteriously implanted in the human soul.[1]

Later, however, when Rome was flooded with foreign immigrants whose *communibus infixa sensibus* belonged to quite a different category from Cicero's, and the uniformity of Latin pronunciation no longer prevailed, especially among the intellectual classes developing the new foreign religion of Christianity, grammarians began

[1] Cicero, De Orat., 3, 195; Orator, LI, 173. It is the context of these passages that is significant.

to concern themselves with phonetic standards. The late imperial and early medieval Latin grammarians thus developed theories of phonetics whose main purpose was to harmonize the two essentially different systems of Latin phonology—the classic system with its tone-length and pitch differentiation of syllable units, and the popular system of the later empire with an energy and stress differentiation of syllable units.[2] The student of philology will find in Martianus Capella's "de Nuptiis Philologiae et Mercurii" (c. 400 A.D.; first printed in 1499) the phonetics which ultimately prevailed to become the foundation of the Renaissance teaching of the language.

Since the written forms of the corresponding syllable units were practically the same in classic and medieval Latin phonology, this phonetics was built up on the supposed constant values of the letters of the Roman alphabet—its vowels *a, e, i, o, u,* together with their digraph combinations, and its consonants, divided into various sub-categories according to the ingenuity of the grammarian.

Renaissance Conceptions of Language

The egocentric conception of language as a divinely given or humanly invented means of *representing* ideas by more or less unchanging written symbols was the only possible basis of philology in the fifteenth century. For the actual phonology of spoken Latin was then a uniform stress phonology, and the phonologies of the chief vernacular languages of Europe which used the Roman alphabet were in substantial accord with it; no one could have suspected the natural laws of development which had been at work for fifteen hundred years to change the fabric of Latin phonology.

The Romance languages, unchecked by literary form and rule, and removed from the restraining social influences of the Capital, had developed so spontaneously and rapidly out of the new stress Latin that their likenesses to their parent had been completely obliterated. The only literary evidence of change lay in the obvious

[2] Many of them were Christians who were familiar with the old quantitative pronunciation and were anxious not only to justify their own stress pronunciation but also to claim for poetry the *psalmi* and new rhythmic *hymni* rapidly developing in the church services. They resorted to various expedients to do this. A common theory was that poetry must be read with a certain *plasma* or *modulatio* through which something is added to a short vowel to make it long—most of their divagations were due to an unconscious lengthening of acute short vowels (Atilius, Diomedes, *passim*—the practice itself is adverted to as early as Quintilian's time, cp. *Inst.* ix. 4. 84.). Another is the naïve explanation that the term "long" is relative, "just as one says that all Germans are tall when as a matter of fact one knows that many Germans are of short stature" (Marius Victorinus, "de Mensura Long. et Brev. Syllabarum," Keil. vi, 39).

inconsistency between the rules of the quantitative classic prosody and the actual phonology of the prose Latin of the Humanists.

But grammarians, whose authority was "*super regem*," had already prepared the ground upon which to reconcile the obvious discrepancy in their tacit assumption that the language of poetry was in some way divinely different from the language of prose. The former, as Beda and Aelfric tell us, depended upon a quantity which conformed to the dictates of human reason (*ratio*), the latter upon a natural quantity which frankly obeyed normal phonetic laws (*natura*).[3]

Thus in their reading of Latin poetry the stresses of Renaissance Latin prose were shifted to conform to the rules of a quantitative classic prosody, and the resulting verses were read rhythmically, developing a proportioned irregularity that was itself considered an element of beauty, a practice and theory that still obtains in many of our universities.

Vernacular poetry was left to follow the dictates of *natura*. The ill-starred efforts of the English Humanists to import *ratio* into English failed to wean English barbarians from Shakespeare's "native wood-notes wild."[4]

This confusion between an assumed *ratio* and an actual *natura*, the product of medieval egocentric thinking, still prevails in one form or another to confuse our teaching of language, and nothing is so irritating to our modern literary criticism as an attempt to treat English poetic form from a purely historical and developmental point of view.

Nineteenth Century Phonetics

The splendid development of the scientific study of language which in the middle of the nineteenth century followed upon Grimm's discovery (1822) that the various Indo-European languages were interrelated by natural laws of phonology, enabled the philologist to escape from medieval egocentric conceptions of language phenomena.

Starting from the fundamental principle that pronunciation is quite independent of the letters of the Roman alphabet, the work of Ellis, Bell, Sweet, and Sievers gave us a system of phonetics whose

[3] This theory was common all through the Middle Ages. Aelfric in adverting to it criticises the popular pronunciation of *pater* with a short English *a* like that in "*fæder*" as detracting from the dignity of the Omnipotent ("Aelfric's Grammatik," Zupitza, Præfatio). It will be recalled that our modern "patter" comes from this pronunciation in *pater noster*.

[4] It must be borne in mind that "wild" in Elizabethan English connoted irregularity, not necessarily violence of passion. The passage is usually construed in its modern English sense.

constants were determined by experimental data interpreted in the light of the facts of language development.

The bases of their classifications were physiological; they assumed that each speech sound depended upon a fixed position of the human speech organs which gave it its peculiar quality, and that the changes which produced language development were due to genetic or racial laxities or inaccuracies in the adjustment of the speech-organ musculature necessary to produce these sounds.

This is the system of phonetics under whose rubrics modern philologists now subsume the data of phonology.

There can be no question that it marked a long step forward in the advancement of the science of language. It is fundamentally sound because physiological data do ultimately determine to a large extent the norms of speech production. It has yielded distinctions of permanent value in giving order and arrangement to the facts of language development, and has produced a system of phonetic representation which, clumsy though it be, is nevertheless independent of the spelling vagaries of particular languages. Indeed, one might justly compare the nineteenth century progress of this science made possible by Grimm's "Deutsche Grammatik" with that which was effected in biology by Darwin's "Origin of Species."

In venturing to propose a new system of phonetics, therefore, the writer would not for a moment derogate from the high excellence of the old, or from the substantial accuracy of the philological work which has been done through its agency. But no modern biologist would be content to base his investigations wholly upon the distinctions found in Darwin's "Origin of Species"; so no modern scientific student of language should be content to stand still at the point reached in Sweet's "History of English Sounds," or in Sievers's "Grundzüge der Phonetik."

The Disadvantages of the Current System with its Physiological Criteria

To the layman our present system of phonetics seems appallingly scientific because the details it presents are so multitudinous as to require a special technical training to comprehend them, and their notation is complicated by a system of mysterious signs. Ellis's "Paleotype Alphabet" contains 267 characters. A like large number are demanded for the phonetic systems of Melville Bell and Sweet. The Oxford Dictionary reduces a phonetic English notation to 98 characters, 64 vowels and 34 consonants. Of course it is possible to simplify these elaborate systems, and this is what is usually done in practice; but phoneticians are not at all agreed as to what

these simplifications should be,[5] and thus phonetic representation ceases to be uniform.

These elaborate notation systems for speech sound result from the assumption that minute differences in the possible positions of the speech organs distinguish one speech sound from another, and that these positions are constant for given speech sounds: *i.e.*, that all speakers produce a given sound in precisely the same way. But recent physiological investigations following upon the development of a more accurate technique for exploring the mouth and throat cavities during speech production are showing that our physiological assumptions do not accord with the facts[6]—in other words, that different speakers of the same sound produce it in different ways. Indeed, the relation of the volume and the ingress and egress conditions of a resonating air chamber to the quality of a sound passing through it is such a delicate physical constant, that to substantiate the assumption upon which our present system of phonetics is founded would require a constancy of size, shape, elasticity and musculature in the human vocal organs that is biologically inconceivable.

Another unscientific characteristic of our present system of phonetics is that it offers us no reasonable explanation of the facts we now know in regard to the development of language. If speech sounds depend upon a uniform anatomical consistency, why do they change, once that consistency is attained? And if they do change, why do all the multitudinous biological factors involved always change correspondingly in precisely the same direction, and to the same degrees, and at the same times, so as to keep language continuously intelligible?

These nineteenth century conceptions of speech phenomena thus present a bewildering multiplicity of distinctions with nothing but uncertain categories to coordinate them, and nothing but accident to explain them—a condition much like that of the botanical sciences a couple of generations ago.

Efforts to determine the Physical Characteristics of Speech Sound by the Study of Phonograph Records

When at the end of the nineteenth century the phonograph became a commercial device, attempts were made to learn something

[5] It is a common tendency of the phonetician to make academic distinctions—"er sieht das Gras wachsen"—and to imagine pedantic sound differentiations which are not heard in his own speech when it is unconscious, and are not normal in the speech of native educated persons who illustrate standard usage.

[6] A paper on "X-ray studies of vowel quality" read before Section L_2 at the Washington Meeting of the American Association for the Advancement of Science by Professor E. Oscar Russell demonstrated this very clearly.

of the physical nature of language by magnifying and examining phonograph records of given speech sounds. Physicists then knew that the cardinal defect of these mechanisms was that free-period vibrations due to the inertias of their moving parts—and these inertia factors were out of all proportion to the inertia of moving air—prevented them from faithfully reproducing the sounds made by the human voice. The record made was always one of air waves plus a number of sound-producing vibrations that had nothing to do with speech. But phoneticians overlooked this difficulty only to find that a careful examination of the magnified record of a given vowel tone showed that it was vastly different for different speakers, and for the same speaker at different times. Thus their attempts to simplify language study by coordinating language phenomena under modern scientific laws independent of speculation only revealed new difficulties.

At this stage of the problem the manufacturers of phonographs called in specialists in acoustic physics with a view to removing the defects of horns, the then means of increasing the force of speech vibrations to the point where they would impress a record on soft wax.

Professor D. C. Miller, of the Case School of Applied Science, was one of those who undertook this task. He first perfected an instrument for precision measurements which would record the motion of a sound wave in x- and y- coordinates with a minimum and calculable amount of distortion due to the free periods of the mechanism—the phonodeik.

Analyzing his phonodeik records into Fourier series for the energy factors of their components[7] he established experimentally Helmholtz's principle that sound quality depends upon characteristic distributions of energy among the partials of a tone through resonance, and determined by Fourier analysis the resonance characteristics of some of the commoner musical instruments. He went on to determine the resonance characteristics of eight sung or intoned English vowels and found that the constancy of their quality depended upon the fact that their characteristic resonance gave maximum energy to one or to a pair of partials whose pitch or pitches were constant for each vowel tone.

For *a* as in *father*, *aw* as in *raw*, *o* as in *no*, and *oo* as in *gloom* the maximum-energy partials were single at 910, 732, 461 and 362, respectively; for *a* in *mat*, *e* in *met*, *a* in *mate*, and *ee* in *meet* the pitch constants were double, 800 and 1840, 691 and 1953, 488 and 2461, 308 and 3100, respectively.[8]

[7] It is an elementary law of dynamics that the energy producing a vibratory motion is proportional to the square of the amplitude multiplied by the square of the frequency: $E = (nA)^2$.

[8] D. C. Miller, "The Science of Musical Sounds," The Macmillan Co., 1916.

Much subsequent investigation by physicists has substantiated Miller's conclusions as to the physical determinants of the quality of intoned vowels, but has also shown that his determinations were too rigid.[9] Miller's determinations and those of the others who confirmed them were grouped according to the traditional "vowel triangle," a kind of metaphysical diagram based upon the supposed physiological criteria of vowel tones.

The writer has shown that, though Miller's *maximum-energy partials* are constant at one or two characteristic frequencies *when a vowel is sung or intoned* at a constant pitch, its quality *when it is spoken in ordinary conversation* is determined by groups of *major-energy components* whose *mean maximal value* is constant and characteristic; and that different speakers to produce the same vowel quality will use different combinations of major-energy components according to the capabilities of their individual vocal organs; and that the same speaker may at will employ various combinations of major-energy components during the production of the successive sound-waves forming the train that the ear recognizes as characteristic of a given vowel tone, and may change its pitch and energy distribution without seriously impairing its characteristic vowel quality. Hence all those delicate shadings of stress and tone inflection which associate themselves with the logical categories and genetic feeling modes of language thinking.[10]

The Bearing of this Work upon Philology

But, one will say, what has all this theory to do with the practical study of language? Doubtless it is very interesting to the physicist, and the improved technique will furnish public lecturers with opportunities to inspire popular audiences with new thrills at the marvels of modern science; yet the fresh complications it reveals seem only to render the fundamental problems of language more hopeless.

Not at all. It has really brought them within the range of definite solutions.

A Fixed Standard of Sound Quality

So long as our standards of speech-sound quality are purely psychological they will be relative and arbitrary. If our measurements of heat variation were in terms of certain psychic effects of

[9] See a very accurate set of determinations for intoned vowels recently summarized and graphically tabulated by Dr. I. G. Crandall, of the Western Electric Company, in the *Bell System Technical Journal* for April, 1924, p. 232.

[10] See "The physical characteristics of speech sound," Bulletin No. 19, Purdue University Engineering Experiment Station, March, 1924.

molecular vibrations upon the temperature-sensation receptors of the average human being, we should really know little about heat from a physical point of view. In like manner if sound quality is measured as *organ-tone, violin-tone, flute-tone, voice-tone,* etc., with *noise* for a sort of omnibus category of sounds that the ear judges to be quite different from those it calls *tones,* our measures of sound quality will be shifting and variable. But once a physical constant of sound quality is established, a measurable scale of speech-sound quality and a scientifically exact method for the study of language become possible.

Resonance the Physical Basis of Sound Quality

Now these recent physical investigations have demonstrated that in spite of all the bewildering varieties of speech sounds, one physically measurable factor runs through them all to determine their significance for a given language, *viz.*, resonance. Without resonance our speech would be as the chirping of sparrows. Sir Richard Paget, in an elaborate series of experiments with a device of his own invention for producing speech sound by purely mechanical means, has recently demonstrated that consonants, as well as vowels, are determined by conditions of multiple resonance characteristic of each; and has actually manufactured most of them in his laboratory by synthesizing their resonance factors.[11] Thus we have at hand means of determining physically the characteristics of *all* speech sounds.

Acoustical instruments of precision have already been perfected to the point where these resonances can be accurately measured. Their effect upon the distribution of the energy in an air-wave train can thus be precisely calculated from mathematical applications of known physical laws. It only remains to establish a constant for the quantitative distributions of energy in the sounds produced by the vocal organs as determined by resonance to enable us to say just what happens in the world of matter and motion when one makes an auditory syllable gesture, so to speak. What happens to the human brain upon the receipt of the gesture from the auditory receptors (or upon the establishment of its image) is a question for the psychologist.

An Absolute Unit for Measuring Vowel Quality possible

How can such a constant be arrived at?

Starting from Helmholtz's principle that the quality of a tone

[11] See Sir R. A. S. Paget, "The nature and artificial production of consonant sounds," Proceedings of the Royal Society, A., Vol. 106, pp. 151–174; cp., also Proceedings of London Physical Society for April 15, 1924, pp. 213, 214.

is determined by an unequal distribution of energy among its partials, whose consequent varying loudnesses the hearing mechanism fuses with the loudness of the fundamental, it is obvious that if the fundamental and partials of a given speech tone were all equally loud the tone would have no quality—merely loudness with indistinguishable pitch.[12]

Since the successive frequencies of the partials of such a tone are integral multiples of the frequency of the fundamental, we have known frequency factors of their energies; and since the energies of its partials are always a constant, the successive amplitudes must stand in the ratio of $\frac{1}{1}, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots$.[13]

As the writer has pointed out elsewhere,[14] to take the total energy of any speech-sound-producing wave and redistribute it in terms of such an assumed quality norm of the same fundamental frequency is a problem of elementary mathematics. Moreover, there can be only one such norm corresponding to a given sound wave. Since each amplitude of our assumed norm is known, by measuring the successive amplitudes of the components of any given speech tone against the corresponding no-quality amplitudes we can determine the energy ratios of its excess components. And since the frequencies corresponding to these energy ratios are in both cases multiples of the same fundamental frequency, we can derive mathematically the frequency of that single component which would represent the mean energy of the excess components, whatever their number or frequencies. This we call our Quality Constant, Q, because, as Miller has shown, it is constant for any given tone quality. This Q, from the way it has been derived, will be *the root-mean-square, i.e., the square root of the mean square, of the frequencies of the excess components weighted proportionately to their respective energies.*

Now the writer has shown that a spoken vowel, as distinct from a sung or intoned vowel, is the effect of an a-periodic sound-wave train of some 10 to 25 waves. But he assumes that the successive individual waves of such a train may be taken as constant for very brief intervals if the change in their form is gradual, and thus

[12] It is of course impossible to produce such a tone on account of the inertia of matter, and the ear could not hear it without disturbances due to imaginary beat tones. If it could exist, its psychic effect on the human auditory-sensation receptors would be analogous to that of white light on the visual-sensation receptors. The contrary effect of pure pitch results from a single tone without partials, a condition which can be approximated by a tuning fork with corresponding resonance sufficient to kill the audible partials.

[13] A curve of the successive amplitudes of such a tone drawn to rectangular coordinates of amplitude and frequency is a rectangular hyperbola.

[14] *Op. cit.*, pp. 39 ff.

determines their constants as a progressive series within characteristic limits. He finds that the mean value of these successive quality constants of a spoken vowel tone of his own voice corresponds substantially with Miller's fixed determination for the same vowel when intoned, arrived at in quite a different way. The psychological reason for this correspondence probably lies in the fact that the clangs of the spoken vowel change so rapidly in a wave-train whose maximum duration is only about $\frac{1}{5}$ of a second that their successive clang qualities produce a single pitch-loudness impression proportionate to the mean of the excess energies of the successive waves. A single wave, therefore, whose clang quality was that of this mean, would, if repeated periodically, produce the same impression.[15] Similarly the changes in the loudness and the pitch of a fusion of spoken vowel clangs are not analyzed into separate sensations but are fused in an impression of constant, increasing or decreasing pitch.

Our Quality Constant is thus a constant energy-frequency ratio based upon Helmholtz's principle of tone-quality, as demonstrated by Professor Miller for intoned and sung vowels, and extended to apply to spoken vowels. It enables us to measure clang quality in terms proportionate to the energy producing the clang impression, and is independent of physiological criteria. For any given quality-producing sound wave Q is the frequency of the single simple sine wave whose excess energy represents the mean excess energy of the major components; and if this single maximum component were substituted for the major components of the system the same clang-quality would result; Q is therefore the theoretical maximum-frequency constant measuring any given clang quality, no matter what the combination of components producing it may be.

The Vowel Tone Spectrum

An application of this method to the spoken vowel tones of English determines for each a series of successive quality constants varying within definite limits; and when these bands of variation are set down as an increasing numerical series, they reveal a succession of quality ranges like those of a color spectrum. This sound

[15] A clang is the auditory impression made by a tone combined with its overtones: the impression is like a simple sensation, and is produced by the simultaneous fusion of the various tone sensations, which lose their individuality in the process. A simultaneous combination of clangs, however, produces a different impression: for in this latter case each clang being a fusion of its *own* components preserves its clang individuality in the combination. (See Wundt, "Lectures on Human Animal Psychology," Creighton-Titchener Trans., p. 73 ff.) We should therefore expect the similar condition assumed above for a rapidly successive fusion of clangs.

spectrum bears a relation to the sound-producing motions of the air similar to that which the color spectrum bears to the light-producing motions of the ether: the qualities of the one, like the hues of the other, are determined by the frequency-energy ratios of the vibrations producing them.

Our simple English vowel tones, ignoring their multitudinous spellings, may be set down in the following table:

I. *boot, two, rule, wound, tune* (Am.)
II. *book, good, poor, full, wolf*
III. *cone, road, dough, sew, trow*
IV. *sung, mouth, fir, earth, rough*
V. *hawk, squash, trough, all, bond, water*
VI. *father, bar, mark, grass* (British), *water* (Middle West)
VII. *mast, bat, man, laugh* (Am.), *aunt* (Am.)
VIII. *meant, said, net, bury, friend*
IX. *sail, say, prey, weight, make*
X. *it, pin, been* (Am.), *peer, sieve, syrup*
XI. *yield, seed, receive, people, machine*

Their clang-quality spectrum is as follows—the energy-frequency figures are provisional:

Our English diphthongs are combinations of clangs separated by more than one intervening band. Our English long vowels, *ā, ē, ū, ī*, slide from one band into a neighboring band with greatly diminished energy.

Now it will be found that the vowels systems of the various Indo-European languages are made up of selections from this spectrum, variously combined or modified.[16] English, however, adequately represents a full complement of these tones. Thus among its other superiorities—and it has so many that the writer has long maintained that English is the most perfect language in the world—the vowel system of our language is the most scientifically complete yet developed by man.

Indeed, there is much good sense in Sir Richard Paget's contention that if we would only give over our efforts to construct an international language and devote our energies to improving our own tongue, English would naturally become a medium of international communication because of its inherent fitness for such a

[16] In some European languages, however, the standard mean value of the bands, especially of *a* or *ä*, is slightly higher or lower than in English.

destiny. But our present system of education regards the scientific study of our native language as among the last subjects upon which to lavish its energy and enthusiasm, and scientific research in this field consequently receives but meager support.

Now it may be objected that our vowel-tone spectrum as determined by the method outlined above depends upon the investigations of a single phonetician into the nature of the tones of his own voice. But it must be borne in mind that his determinations accord substantially with those of a number of physicists of undoubted competency working independently upon intoned vowels and by quite different methods. It is the arrangement of vowel tones in the form of successive single constants which the writer's method yields that is its significant feature. When his determinations are rejected *in toto* and only those of experienced physicists working upon intoned vowels unbiased by phonetic considerations are employed, it will be found that on taking the root-mean-square of their double maximum frequency constants[17] a series of single constants, varying within comparatively narrow limits, can be obtained, which will form substantially the same increasing scale, vowel for vowel, as that given above.

The point we are stressing is that there *is a scale* of vowel tones whose degrees of quality can be scientifically measured independently of the ear, once a constant starting point is determined.

That the one we have attempted to establish bears a scientific relation to the production of language, and is no mere creation of a vagrant fancy is evidenced by the fact that it explains phenomena of language which have long been recognized.

Philologists are aware that the vowel tones of language are very unstable as compared with the consonants. With the exception of a few peculiar consonants the learner of a foreign language can quickly acquire the ability to reproduce its consonants with accuracy, because most of them are phonetically identical with those of his own. But to reproduce its vowel tones in such a way that a native will detect no strangeness in them is quite a different matter. It is also a well-known fact that it is hopeless to teach a student phonetics without first training his ear to hear the delicate variations of vowel quality which his untrained ear will never detect.

This inability to hear the finer shades of quality is, however, confined to speech sound. The untrained ear has no difficulty in

[17] A root-mean-square is a quadratic mean; since frequencies enter into energy in terms of squares, the method is quite logical, assuming that the energies of the twin maximum components are equal; if unequal, this figure will be proportionately nearer the frequency of the component which has the greater energy.

distinguishing a flute from a violin or in recognizing a person by his voice. It has already been pointed out that if the language depended upon a uniformity in all the qualities of speech tone it would be unintelligible because of the anatomical variations of individual speech organs. When we are listening to speech we identify only the major components of the tone and do not hear its minor components.

As the actual sound quality of the major components is always being modified by that of the minor components, it is obvious that the vowel qualities may be variable without impairing intelligibility of the speech gestures of which they are the nuclei.

What is the limit of this variability?

There are many known facts of phonology which point to the conclusion that the variation range of vowel quality can not cover more than two bands of our spectrum without making a given language unintelligible. We have not space here to specify these details, but we may summarize them as follows:

(1) The local variations which give some of us so much concern when disputing the correctness of English pronunciation will usually be found to be due to the shifting of one quality band to the neighboring one.

(2) The chief differences between British and American pronunciation of English are characterized by the fact that the one standardizes one band under certain conditions, and the other standardizes the one next to it.

(3) The historical development of English phonology for the last thousand years illustrates a succession of periodic shiftings of its vowel tones from one quality band to that immediately adjacent.

These facts point to the conclusion that development in language is largely due to the principle that two neighboring bands of quality constants can exist side by side in a given speech and the language still be intelligible. One of these bands becomes standard and general and the other is forgot, only to give rise to a repetition of the process.

If our theory is the true one we should expect to find confirmation of it in the historical development of the Indo-European languages as a group. Any philologist who will take down his Brugmann's "Grundriss der vergleichenden Grammatik der Indo-Germanischen Sprachen" and trace the tone developments of the various language sub-groups will find that a surprisingly large number of them conform to our principle.

We thus have in the new work in acoustic physics a means of getting at principles of language that are fundamental not only

from a mechanical and engineering point of view, but are also fundamental to a truly scientific conception of the essential nature of language, to an intelligent teaching of it as a means of culture, and to practical methods of ensuring its highest efficiency as a means of communication.

Much remains to be done along these new lines in the way of ascertaining and completing our physical data, and of determining precisely how they relate themselves to the psychology of speech production and interpretation and to the historical development of language forms and modes. But physical science has at last given us a *pou sto* in fact upon which to organize our knowledge independently of speculation and opinion.

If those who study these problems with educational and cultural aims can only be furnished with such opportunities and resources for solving them as are commanded by those who approach them from a commercial point of view, there is little doubt that the next generation will attain a complete scientific understanding of this the most vital function of man's intellectual activity.

THE STATE OF SCIENCE IN 1924[1]

THE BIOLOGICAL ACTION OF LIGHT

By Professor D. T. HARRIS

THE distribution of solar energy over the British Empire shows immensely wide variations, and inhabitants of the large cities of Britain probably receive the smallest share. It is only in recent years that the London child sufferer from tubercular joint disease has had the chance to enjoy sun baths. The pioneer work of Sir Henry Gauvain at Alton and Hayling Island has demonstrated conclusively the curative action of the sun's rays in bone and joint disease of tubercular origin. The wonderful results of Dr. Rollier in Leysin, in the Swiss Alps, show on a more extensive scale the beneficial effects of insolation at high altitudes. To Dr. C. W. Saleeby is due the credit for bringing this powerful agent to the notice of the English-speaking public. It was through his untiring efforts that the Medical Research Council appointed a committee to investigate the biological action of light, under the chairmanship of Sir William Bayliss, who was the first to write an authoritative account of this youthful and difficult subject ("Principles of General Physiology," Longmans).

The investigation of the mode of action of an agent like light, to which we and our ancestors through the ages have grown so accustomed, presents unusual difficulties; we are apt to accept it as an unanalyzable fact. No one will question the existence of the stimulating effect of the morning sun, but to determine the tissue on which it acts and its mode of action, whether chemical or electrical, is a problem demanding the cooperation of physiology, chemistry and physics.

The physicist continues to make his valuable contributions. The colors of the rainbow, which represent the visible part of the spectrum, are now known to be only a very short link in a huge electromagnetic spectrum connecting the immense waves of wireless telegraphy, on one hand, with the extremely small X-ray waves, on the other. All these waves travel at about the same speed, eight times round the earth in one second. To-day there exist but few gaps in this electromagnetic spectrum. On the red side of the visible spectrum we pass into the region of dark heat rays, includ-

[1] Prepared for the Hand-book to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

ing those emitted from a hot flat iron. These, though invisible can be appreciated by the heat receptors in the skin of the cheek. Dark-heat or infra-red rays, constitute about half the energy we receive from the sun. On the more active violet side of the visible spectrum the waves are only half the length of the red waves, and as we pass beyond the faintly visible violet we come to a chemically active region called the ultraviolet, where the waves average only half the length of the violet. These ultraviolet rays are proportionally few in sunlight; they are absorbed by ordinary window glass, and so can not enter a house with closed windows. They are also reduced in intensity by absorption in the atmosphere, and hence are more abundant at high altitudes, as in the Alps.

It has been supposed that man through the long ages has become immune to the visible rays of the sun. It is only when the infra-red rays become excessive that he seeks the shade, and in this way he also escapes from the destructive action of a too powerful dose of ultraviolet light. It is the infra-red which are the potent rays in the causation of sunstroke, whilst the ultraviolet cause sunburn. The latter may be easily demonstrated by exposing an area of skin for five minutes to the ultraviolet light obtained from an artificial source rich in ultraviolet rays—*e.g.*, the mercury vapor lamp in a quartz tube; the other rays can be filtered off, the heat rays by a water cell and visible rays by a cobalt-quartz plate.

This powerful action on the human skin is of great interest. After the sunburn subsides the majority of people develop pigment. If now the same region of skin be exposed to ultraviolet light, it will be found that a burn does not appear on the pigmented skin, but only on the neighboring unpigmented skin; protection has therefore been conferred by the development of pigment. This experiment suggests the mode of evolution of the pigmented races of the tropics. How the pigment actually works, especially in view of the fact that a black body is a better absorber of heat than a white body, is a problem under investigation.

Another effect of ultraviolet light and one which has been definitely proved is its destructive action on bacteria, and this has been applied commercially to the sterilization of water by passing the water in thin sheets over quartz cylinders in which are placed large mercury vapor lamps.

Ultraviolet light appears to play a very important part in the growth and development of the young child, and may prove to be one of the chief agents in the prevention of the bony deformities known as rickets. The results of some experiments seem to point to the conclusion that ultraviolet acting alone is a more powerful agent than when acting in the presence of the visible light. Indeed,

the writer found that the stimulant action of ultraviolet light on the total chemical changes in the body could be annulled by the addition of visible light; a similar antagonizing action of the visible light was found on the tonic effect of ultraviolet on the isolated stomach kept alive with oxygenated Ringer's fluid.

As only a very short unexplored region exists between ultraviolet radiation and X-rays in the electromagnetic spectrum, it is probable that many of the problems of the biological action of these two types of radiation may be solved simultaneously. Two outstanding differences, however, exist between them. The ultraviolet rays produce their effect in a few minutes, and their direct action is entirely superficial, while X-radiation sometimes takes weeks to reveal its effects, and it penetrates deeply into the tissues, and is only stopped by dense structures like bone. The rays from radium produce effects on the tissues very similar to those of X-rays.

May we hope that the investigation of these artificial radiations in the laboratory will yield the secrets of the beneficial action of sunlight, and that man's activities will be directed to the removal from our atmosphere of the suspended matter which at present cuts off the health-promoting (ultraviolet?) rays. It is a matter for some regret that the empire on which the sun never sets has not developed great institutes for the open-air treatment with sun baths of the young victims of the darkness of our large cities.

MUSCULAR WORK

THE MECHANISM

By Professor A. V. HILL, F.R.S.

BODILY movement is an apparently simple phenomenon and its characteristics can be measured in absolute physical units. For example, the work done by a contracting muscle can be measured in ergs and as accurately as the work done by a steam engine. The mystery of how the muscle fiber performs its important and easily recognized function has long appealed to those who desired to study living response in a form approachable by methods of exact science. Moreover, there was the hope that, once a beginning had been made, the results and generalization attained by studying muscle might be found to apply to all other forms of living tissue, and so a way be found of bridging the gap between biology and physics: the continual exploration of the problem of how a muscle works was dictated by a far-seeing strategy.

The subject is full of great names, Helmholtz, Fick, Blix and many others. Of British workers Gaskell's and Mines's researches on the isolated heart have proved the fundamental basis of modern cardiology. W. M. Fletcher perceived the extreme importance of the fact that oxygen delays the onset of or abolishes fatigue in an isolated muscle: W. M. Fletcher and F. G. Hopkins, working together, recognized that lactic acid was the key to this phenomenon and that the percentage of it in a muscle is high in states such as fatigue and *rigor mortis*. From the original papers of Fletcher and Hopkins has arisen a network of investigations, illuminating many branches of physiology and throwing sidelights on several aspects of medicine and everyday life.

When a muscle contracts, lactic acid is liberated, in amount proportional to the strength of the contraction: when it relaxes lactic acid is neutralized: while the contraction is upheld, a balance is maintained between continual production and continual neutralization. During the succeeding ten minutes restoration occurs: the lactic acid is slowly removed in the "recovery mechanism" of the muscle, but only if oxygen be present; it is restored to its previous state, the necessary energy being provided by the oxidation of a fraction of the lactic acid. The system is analogous to an electrical accumulator, together with a motor and a dynamo; the accumulator can rapidly provide mechanical work when needed, but must be slowly recharged afterwards by the use of energy required to drive the dynamo. Oxygen in muscle is used only in recovery from previous exertion: even during exercise, each element of the oxygen consumption is used in recovery from a previous element of effort.

The lactic acid arises from and is restored to glycogen, a body peculiarly important in connection with modern work on carbohydrate metabolism, "insulin" and diabetes; indeed, the fact that, in muscle, glycogen breaks down more readily than does glucose into lactic acid suggests that a study of the chemical nature of glycogen and its reactions in the muscle mechanism of the frog may find some strange and interesting application to the problems of human diabetes.

The onset of fatigue is due to the accumulation of lactic acid in the muscle: the limits of violent effort are set by the maximum amount of acid which the body can tolerate. During exercise and in the earlier stages of recovery the acid passes into the blood; part of its oxidative removal may even occur in distant portions of the body. The labored respiration accompanying, and following, active exertion is due to acid in the blood stream, affecting the respiratory center in the brain. The labored respiration occurring even after moderate exercise, in some forms of cardiac or other disease, is due

to acid appearing in the blood as the result of an imperfect mechanism for its oxidative removal. The beneficial effects of previous inhalation of oxygen before a race are probably due to the solution of a store of oxygen in the tissues of the body: the beneficial effects of oxygen during recovery or in fatigue are due to the more rapid oxidative removal of the acid. The changes occurring in the blood, as the result of exercise or of oxygen want, in its combinations with oxygen and carbon dioxide, are partly due to lactic acid.

It would seem a far cry from the obscure labors of physiologists to the making of records in athletics. Yet a study of the oxygen intake and the carbon dioxide output in man, during violent exertion, together with the results of recent work on the dynamics, thermodynamics and chemistry of isolated muscle has shown otherwise. A man's capacity for muscular effort is limited by precise and clearly defined factors, depending upon his supply and utilization of oxygen, his economy in movement, his efficiency in recovery and the maximum amount of lactic acid to which his body will submit. The general type of relation existing between the distance (in a flat race) and the speed at which it can be run, can be predicted on comparatively simple physiological grounds. It has been the writer's good fortune, though himself an inconsiderable performer, to have had for many years a close personal acquaintance with athletes and athletics: and it has been recently almost a daily pleasure and excitement to find some phenomenon, known to runners, turning up again in another form in the physiological laboratory. Mountaineers, airmen, students of human movement in industry and everyday life will find the same.

We must recall, however, that it was the pure science which found the path and built the bridge, and we are really only at the beginning of our knowledge of muscle: the adventurer's instinct is still needed: it is necessary to explore as well as to exploit.

The recovery process, capable of completion only in the presence of oxygen, still goes on in part, even in its absence: the details of the process are unknown. The course and magnitude of the liberation of energy associated with all phases of contraction and recovery have been described, and it remains for the chemist to fit his details into the thermodynamic picture. Again, there are many curious and complex effects, connected with the actual shortening process itself: changes in energy liberated, changes in work done, changes in mechanical efficiency. There are the physico-chemical factors underlying the power a muscle possesses of using oxygen: there are the highly specific actions of certain drugs upon the mechanism. But behind them all remains the mystery which causes the physiologist

to smile at the simplicity of other sciences, the mystery which appeals to the artist in him, the solution of which—still so far away—offers so fruitful a field of understanding and healing men's bodies: the mystery of the little fiber, about 1/500 of an inch thick, designed and constructed in a material not unlike egg-white, growing, feeding, repairing itself and exhibiting in its function so admirable a simplicity, an efficiency and a directness of apparent purpose.

THE ENERGY OF EXPENDITURE

By Professor E. P. CATHCART, F.R.S.

ALTHOUGH man is no machine in the ordinary sense of the term, he, just like the locomotive, must be supplied with fuel for the production of work. In the case of the locomotive, however, the fuel is only required for the performance of work, whereas in the case of man the fuel—food—not only supplies the necessary energy for the performance of work, but it also serves for the repair of the wear and tear of the tissues and for growth. Before a correct assessment can be made of the amount of food required, it is necessary to determine the amount of energy expended.

This question of the best and most accurate method for the determination of the energy expended is no new one. The first experiments, which changed the whole outlook on the problem, were made almost at the same time, about 1780, by Crawford in Glasgow and Lavoisier in Paris. Crawford indeed claimed priority, but his insight into the problem was not so fundamental as that of his French rival. The method then adopted is in essentials the one we use to-day. It consists in the estimation, either directly or indirectly, of the amount of *heat* lost. The thermal unit or calorie is chosen because eventually all the potential energy of the food consumed or the tissues oxidized is reduced to heat, and, further, the external work done can also be measured in heat units. Thus by the use of the calorie we obtain a common factor for the statement of energy problems. The calorie used to-day by physiologists throughout the world is the large or kilo calorie which represents the amount of heat required to raise the temperature of one kilogram of water through one degree Centigrade. The amount of external work done is calculated in kilogram-meters—*i.e.*, the amount of energy expended in raising one kilogram vertically through one meter distance. Largely from the pioneer work of Joule, of Manchester, we know that approximately 427 kilogram-meters equal one large calorie.

The amount of energy, calculated as calories, contained in the food consumed is determined by burning a definite amount of the

food material, under very definite conditions, in an apparatus called a bomb calorimeter, and measuring the amount of heat liberated. A great many of the earlier determinations of the calorie values of foods were made by Frankland, of Birmingham, in 1866. The estimation of the energy lost by the living organism or man may be carried out either directly or indirectly. In the direct method, which was the one originally adopted, the amount of heat given off by an animal was measured by noting the increase in temperature of the cold water or ice which surrounded the chamber in which the animal was placed. The modern development of this method has been for the most part confined to America and is associated with the names of Atwater, Rosa, Benedict and Lusk.

The indirect method, which is much easier and less expensive, has been developed chiefly in Britain and in Germany. Although a somewhat similar method was adopted by Smith, in London, so long ago as 1859, Zuntz, of Berlin, was the first to devise a trustworthy and portable apparatus, but it had the drawback of being heavy and cumbrous. The method introduced by J. S. Haldane and C. Gordon Douglas, of Oxford, is infinitely better, being both accurate and easy to use. In this indirect method, the changes in the composition of the inspired and expired air are measured. The subject, with his nose "clipped," breathes through a special mouthpiece (or a special face-piece) equipped with two one-way valves, an inspiratory and an expiratory. The mouthpiece on the expiratory side connects by means of rubber tubing with an airtight bag which serves to collect *all* the expired air for the period of the experiment. The amount of air expired is measured by passing it through a meter, and a sample of this air is taken for analysis.

The analysis shows, as compared with the composition of the normal inspired atmospheric air, an increase in the content of carbon dioxide and a diminution in the amount of oxygen. The alteration is due to the combustion of the various foodstuffs in the tissues. The amount of oxygen used is multiplied by a factor, which is obtained from the ratio of the amount of carbon dioxide breathed out to the amount of oxygen utilized, and the result is a statement of the energy expended in calories. The assumption is made that the amount of oxygen utilized is a direct index of the amount of material burnt in the tissues. That this assumption is correct is shown by the fact that from a series of double estimations made by the direct and indirect methods the two varied in their final result by less than 1 per cent.

As the apparatus can be utilized for the determination of the energy expenditure of mobile subjects, it is possible to examine and compare the energy expended by a great variety of workers. It is

possible to assess and compare the cost of work, for example, of such very diverse occupations as postmen, riveters, tailors, clerks, etc.

If, however, it is desired to study more particularly the various phases of energy expenditure, it is customary to make the subjects perform given amounts of work on special types of apparatus known as ergometers (work-measuring machines). These machines are of different types; some are used for the investigation of work performed by the arms either of rotary or lever movement, whereas others have been devised, such as the "walking" platform and the bicycle ergometer, for the study of the cost of movement of the leg muscles. As a general rule, the work done consists in rotating a wheel against resistance which can be varied within wide limits. Under these conditions, it is possible to carry out very accurate determinations of the actual amount of work a man can perform in the course of an hour, or eight hours, or any other given unit of time.

A number of investigations have been made of the energy expenditure in various occupations by this method of indirect calorimetry, but a great deal of work must yet be done before anything like final conclusions can be drawn regarding the average energy expenditure of any class of workers. In spite of the importance of this subject, which is in reality the basis for the study of the nutrition of man, Britain possesses no institute or laboratory specifically devoted to the study of the nutrition of man, although it has at least two institutes for the study of the nutrition of farm animals.

ICE RIBBONS

By Dr. W. J. HUMPHREYS

U. S. WEATHER BUREAU

Did you ever see the Christmas ribbons Jack Frost ties about *Cunila?* If not, and if you are a lover of the beautiful in nature, then hunt for them any cold morning of early winter, when the ground is neither frozen nor covered with snow. Where? Almost anywhere along the whole Appalachian system and its borders, the home of *Cunila—Cunila origanoides,* to be exact—Jack Frost's especial favorite. A few other plants receive a little of his ribbon gifts, but mere scraps and ends left over from the lavish adornment of his particular pet.

"Cunila" is the old Latin name of a plant of some kind, no one knows what, while "origanoides" means "like origanum" (wild marjoram), whose name, also Latin, was adopted from the Greek in which it signifies delight of the mountain. No wonder then many of us, perhaps even botanists too when off their formal guard, prefer to call this aromatic herb by some simpler name, such as stonemint, or American dittany.

But call it what you will, this plant, about a foot to eighteen inches high, and having in late summer many small purple flowers, Fig. 1, is common in the eastern portion of the United States. Its somewhat angular stem has a pithy core and a woody shell threaded with long and large sap ducts, the supply tubes during the growth of the ice ribbons.

The stem dies in the autumn, but the roots live on and the sap tubes through capillary action remain full of water up to some inches above the ground. Then when a freeze sets in, from one to several, but usually two, ribbons of ice start growing out from the side of the stem, each as if (though actually not) from a wide crack or slit. The ribbons are about as thick as the blade of a table knife, half an inch to two inches broad, roughly, and of varying lengths. Those shown with the key, Fig. 2, were each about seven inches long. An occasional ribbon is nearly transparent, but the great majority are snow white. All are fibrous with a silky sheen, the fibers running lengthwise of the ribbon. Nearly all, too, are gracefully curved, as shown in the pictures, Figs. 2 and 3, and, at a little distance, look like so many large white flowers.

The earliest account of this strange ice formation that has come to my attention appeared in 1824, in the second volume of Stephen

FIG. 1. *Cunila* in bloom.

Elliot's "Sketch of the Botany of South Carolina and Georgia." In 1833 Sir John Herschel published in *The Philosophical Magazine* a brief account of the same phenomenon, though less well developed, on the stems, near the ground, of thistles and heliotropes. The first careful study of these ribbons, on a different plant however, *Pluchea* or fleabane, was made by the physicist John Le Conte, then at the University of Georgia. He found that they are owing neither to frost deposition nor to physiological action—the stem of the plant being dead—but, presumably, to the progressive freezing, at the surface of the woody portion of the stem, of water brought from the ground by the porous central pith and forced out along the medullary or pith rays. He also showed that the ribbons did not grow out from perceptible rifts or longitudinal cracks in the stem. His interesting report, presented at the third, or Charleston, S. C., meeting of the American Association for the Advancement of Science, March, 1850, is given in full in the third volume of the Association's *Proceedings*. In 1893 Lester F. Ward published a

brief and interesting description of these ribbons in volume 18 of the *Botanical Gazette;* a short, illustrated account of them, under the title "Frost Flowers," was given also in the Missouri Botanical Garden *Bulletin* for October, 1924.

However, more than sixty years passed after Le Conte's studies before this subject was again seriously examined. This last investigation, by W. W. Coblentz, published in the *Monthly Weather Review,* and also in the *Journal* of the Franklin Institute, in 1914, is the most elaborate yet given to the formation of these ice ribbons. Coblentz confirmed in the main the earlier conclusions of Le Conte, but showed that the supply of water from the ground is by way of the large sap tubes in the thin woody shell of the stem and not the central pith. He also showed that the ribbons form readily on dead stems stuck in damp soil or vessels of water, thus proving that the root system is not essential to, and presumably takes no part in, the supply of moisture. He found too that the ribbons begin as a row, along and normal to the stem, of closely spaced hair-like crystals. These are soon bound together by a connecting web of ice, and the whole grows out to a greater or less extent, a fringe at first and then a ribbon of ice. Furthermore, the ribbons form repeatedly, freeze after freeze, at the same place on the stem.

Apparently then it is established that the ice ribbon is produced by the freezing of water that rises, by capillary action, in one or

FIG. 2. A pair of ice ribbons, each about seven inches long, from a *Cunila* stem, at Huntington, W. Va., December, 1924. (Dr. L. W. Humphreys, photo.)

FIG. 3. Fibrous ice ribbons from *Cunila* stems, at Huntington, W. Va., December, 1924. Length of comparison knife handle, three inches. (Dr. L. W. Humphreys, photo.)

more sap tubes, and comes to the surface mainly, if not wholly, through a row of minute openings, and that this water comes from the soil directly and not by way of the live roots. But is the water that is fashioned into a ribbon supplied by a single tube or by many? What is the nature of the openings from the supply tube or tubes to the surface? Are they finer capillaries inherently present, or mere ruptures or partial tears incident to the drying of the dead stem, or owing indeed to some other cause? Why does not the water in the capillaries also freeze? Is this owing to the liberated heat of fusion, to impurities that the process of freezing tends to concentrate within the supply tubes, to both of these, or even, in part at least, to some entirely different factor?

But why investigate these trivial matters? Because they occur, and we do not fully understand how.

THE FIGURED STONES OF WURZBURG

A Remarkable Hoax in the History of Science

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At no period in the history of the growth of science did there exist a greater confusion of antagonistic interpretations of natural phenomena than in the troublous times which followed the Reformation, a period embracing the latter half of the seventeenth and the earlier half of the eighteenth centuries. The rapid accumulation of new data in all fields of study clamored for correlation and interpretation; nor were correlations and interpretations wanting. Theories and counter-theories, hypotheses and counter-hypotheses were legion. Each new perplexing question propounded at once gave birth to a host of theories and interpretations more perplexing still.

Of the many vexatious problems which were presenting themselves in the rapidly growing fields of zoology and geology, perhaps the one which caused the keenest intellectual contention was the question concerning the origin and significance of fossils. The occurrence of the forms of bizarre fishes, plants, and other organic beings imbedded within the strata of the sedimentary rocks proved to be too much for the early scientific minds to explain with any degree of mutual satisfaction. The general helplessness of the majority of the paleontological scholars when confronted by this problem can be inferred from the many amusing and non-committal generalities which they advanced in explanation. Thus the presence of fossil forms in the rocks was variously accounted for by "stone making forces," "formative qualities," a growth from seeds, and the like. Even the much-abused doctrine of spontaneous generation, then almost in the heyday of its authority, was brought forward to lend its aid.

The influence of the Reformation was, at first, distinctly unfavorable, nay, even hostile, to the spread of the ideals of scientific progress. So robust was the opposition of the reformist leaders to anything like unfettered scientific research that the period immediately succeeding the Reformation was characterized by even more intolerance for the scientific viewpoint than that which marked the Reformation itself. The vestal flame of purely secular scientific philosophy was not entirely quenched, however, and later in the century it waxed stronger and more vigorous, expanding into a

FIG. 1. Some of the "fossils" among those first buried by the jokers.

FIG. 2. "Fossil" birds, some with eggs.

sturdy glow here and there, the earnest of a wider conflagration, which, at a later period, was to illumine the field of science with no uncertain light and point the way for such men as Buffon, St. Hilaire, Lyell, Darwin, and a host of others.

The old spirit of antagonism toward secular and non-Aristotelian scientific thought still retained much of its pristine power, and until as late as the middle of the eighteenth century exercised a no mean measure of judicature over matters scientific. Thus it was that when Buffon, then professor at the Sorbonne, made a modest attempt to set forth what he considered to be a body of irrefutable geological statements, the theological faculty of that venerable university, incensed at his temerity, deprived him of his honorable position in the university, forced him to recant and in the most ignominious manner to print and publish his recantation.

It was during this period of intellectual storm and stress that there was published at Wurzburg a work which stands out in prominence as a memorial at once of an almost incredible hoax, a colossal farce and a pitiful story of broken ambition and humbled pride; a work in one volume, quarto, entitled the "Lithographiae Wirceburgensis." Dr. Johann Bartholomaeus Adam Beringer, its author, lived during the first half of the eighteenth century, and

at the time of the publication of the work which has made his name known held the honorable degrees of doctor of philosophy and of medicine from the University of Wurzburg, occupied a chair in natural philosophy and was private physician to the reigning Prince Bishop. He had already distinguished himself by his scholastic activities in the university, and was widely known as a capable and learned classical scholar, physician and natural philosopher. He had been the author of an able medical treatise in 1708, the "Connubium Galenico-Hippocratium," and had contributed to the literature of Botany some fourteen years later in a systematic work entitled "Plantarum Exoticarum Perennium Catalogus." By his colleagues in the university he was rapidly becoming known as a paleontologist until his unfortunate venture upon the subject of the figured stones of Wurzburg, in 1726. The episode upon which the career, reputation and life of the philosopher of Wurzburg was wrecked we will now recount.

FIG. 3. Various "fossil" absurdities in modifications of marine forms.

Beringer had wholly, publicly committed himself to the belief that fossils were merely the capricious fabrications of God, hidden in the earth by Him for some inscrutable purpose; possibly, thought Beringer, merely for His own pleasure; possibly as a test for human faith. His tenure of this position became so strong and so zealous that some of the students from the university, together, possibly, with some of the members of its faculty and wags from the city, determined to put his faith in this doctrine to a trial *fort et dur*. They accordingly made numerous "fossils" of clay (Fig. 1) which they buried upon the side of a hill near Wurzburg amid some thick bushes, a spot where they knew the worthy professor was wont to ramble in his search for specimens. In accordance with their hopes, Beringer chanced upon these "fossils" in one of his geological excavating tours; was completely deceived as to their true factitious nature, and, overjoyed to discover such suppositive proofs of the validity of his views, made known the facts of his discovery at the university. The jokers, perceiving with glee the success of their trick, now went even further and buried the most fantastic

and extravagant clay figures which their whimsical imaginations could suggest (Figs. 2, 3 and 4). Not content with these alone, they fashioned inscriptions in Hebrew, Babylonian, Syrian and Arabic (Fig. 5), one of these being the name of God Himself! These they buried not far from the spot where they had concealed the first.

The elation of Beringer on discovering these latter "fossil" forms was unbounded. He was now completely convinced of the soundness of his original doctrine and at once made impressive preparations to publish a full account of his discoveries and to elaborate learnedly and at length upon their profound signification, animated by no meaner motive than to settle once and for all time the vexatious question relative to the origin of fossils.

The fervor of the once cautious man of science swept all before it, and, despite the temperate advice of more level-headed colleagues, Beringer hurried the ponderous work to its completion, and in due time the volume appeared. The book itself, a tome of commanding proportions and written in Latin, consists of an ingenious allegorical frontispiece (Fig. 6); a title page devoted chiefly to the record of Beringer's positions, degrees and honors; a dedication plate, followed by a nine-page dedication; a preface of about equal length; fourteen chapters, forming the body of the work; and twenty-one plates containing the figures. The title page informs us that the book is the: "Lithographiae Wirceburgensis, illustrated with the marvelous likenesses of two hundred figured, or rather insectiform stones," by "D. Joane Bartholomaeo Adamo Beringer, Philosophiae et Medicinae Doctore . . . etc.," and printed in Wurzburg in 1726. Some contribution to the work was made by one Georgius Ludovicus Hueber, who is also mentioned on the title page, but the bulk of the work is the result of the painstaking labors of the worthy and credulous doctor of medicine and of philosophy.

The sounding and pompous dedication, nine full quarto pages long, is to D. Christopher Francis, Prince Bishop of Wurzburg. "Most Revered and Most Eminent Prince and Merciful Lord." It begins with an exposition of the frontispiece, and its significance, which is an amazing and pretentious allegorical representation of the suppositive profound signification of Beringer's discoveries (Fig. 6). In the center rises a mound composed of the "figured or rather insectiform stones," upon which recline (as significative of their debt to the truth established by the work) the patrons of the various arts, as well as teachers and children. Midway up the mound is the figure of divine child-messenger tracing upon its tablets the inscriptions which Beringer had discovered. In the foreground, to the right, stands a table, bearing the follow-

ing passage from Ovid (Metamorphoses, Bk. I, 1:436). "It [the earth] brought forth innumerable forms; some like unto those which had existed before, and some new monsters."

But the most dauntless portion of this allegorical picture is the delineation of the arms of the reigning prince and the triangle of the Holy Trinity (the latter signifying the glory of Heaven), both represented, as magnified by the work of Beringer, by being placed upon the summit of the mound!

FIG. 5. The climax of the hoaxers' art. The "fossil" inscriptions in Hebrew!

After the preface or *Praeocmium* come fourteen chapters containing a full account of the discovery of the stones, the methods which the author had used to safeguard himself, as he thought, against making errors in the interpretation of his data, the description of the hill where the digging had been carried on, the progress of the work at the university, and so forth. He carefully refutes in advance the view that the figured stones might possibly be vestiges of the early "pagan" occupation of the land, *i.e.*, the occupation by the Gauls. We can picture to ourselves the fervor of the old scholar as he labored over his great work, the *magnum opus* of a life of scientific devotion, his thoughts dwelling fondly, and not a little proudly, perhaps, upon the expected acclamation with which the book would be greeted by his contemporaries in science and philosophy. Not only would his proofs of God's direct agency in the formation of fossils be the

FIG. 4. "Fossil" comets, stars, crescent moon, and a minor sun with a face!

coup de grace to purely secular science, but it would undoubtedly forever lay the ghost of that troublous matter of the origin and meaning of fossil forms. No doubt the idea of the allegorical frontispiece came only after he had labored long upon the manuscript of the "Lithographiae" and had pondered over the enormous authority which it would one day wield in the world of scientific thought. In chapter after chapter the author anticipates and

FIG. 6. The exuberant frontispiece of Beringer's great work. Note the arms of the reigning prince and the triangle of the Holy Trinity surmounting the mound of "fossils"!

refutes objections to his views concerning the *lapides figurati Wirceburgensis,* always reverting to his tenet of their fabrication and concealment by divine decree. He describes gravely the Hebrew, Arabic, Babylonian and Syrian inscriptions which he had unearthed, commenting upon the nicety with which they had been fashioned, and upon their excellent state of preservation. Some of these inscriptions occur on shells and images of animal forms.

And now comes the strangest part of this humiliating story. Some of Beringer's friends, partners to the secret, alarmed at the

length to which he was pursuing this prodigious fraud, endeavored to dissuade him from the publication of his book. And even though others, who knew more intimately the secret of the trick which was being played upon him, acquainted him fully with its shameful history, yet he obstinately refused to give their stories credence. In one contemptuous chapter he dismisses all their evidence, denouncing it as a ruse of his rivals to deprive him of the honor of making known his discoveries, and of publishing so important a contribution to science. He argues that, since the workers employed by him to unearth the fossils knew no tongue save their own, they manifestly could not have made inscriptions in Hebrew, Arabic, Babylonian and Syrian. Needless to say, he had first convinced himself that no one save he and the workers (as he says, "some boys of tender age") had ever set foot upon the mountain whence had come the marvelous insectiform stones.

His work being at length completed, and in spite of the now more robust efforts of his colleagues to prevent publication, he published it and appealed to the learned world. But the shout of laughter with which the book was received was not to be misinterpreted. In chagrin, anger and despair, the broken-spirited man exhausted virtually his entire fortune in the fruitless endeavor both to suppress the publication of the book and to buy up all the copies which had been issued. For a short time he lived, the object of the mingled ridicule and pity of his contemporaries, and not long after died, as tradition tells us, of a broken heart.

But the wrecking of Beringer's reputation did not cease with his death, for a graceless bookseller, Hobhard of Hamburg, seeing his opportunity to make capital of Beringer's shame, bought up all the available copies from the heir of the original publisher and not only reissued them, but, compiling a second edition, brought out the work under a new title and turned this also into circulation!

Poor Beringer! His woes have been great, and his demand upon posterity is one for large pity. Very few of the prominent personages in the history of science stand so in need of our heartfelt sympathy as Johann Bartholomaeus Adam Beringer, doctor of philosophy and of medicine in the University of Wurzburg, and private physician to the Prince Bishop.

(For accounts of Beringer's work see, first of all, the "Lithographiae" itself. None of the accounts are complete, and give but short résumés; these are: Allgemeine Deutsche Biographie, Vol. 2; Ersch u. Grüber, Encyclopädie d. Wiss u. Künste, Leip. 1818–90; Reusch. Bibel u. Natur, Freiburg, 1866; Reuss, Litterarisches Curiosum, in the Serapeum, 1852, Vol. 13; Zöckler, Geschichte d. Beziehungen zw. Theologie u. Naturwissenschaft, Gutersloh, 1879, Vol. 2, p. 171.)

YOUTHFUL ACHIEVEMENTS OF GREAT SCIENTISTS

By GEORGE P. MEADE
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SOME years ago Dr. Osler gained much publicity by something he did not say. He was credited popularly with saying that all men over 40 were useless and advocating chloroform for all men at 60. According to the International Encyclopedia what he did say was, "Take the sum of human achievement in action, in science, in art, in literature; subtract the work of the men above 40—we should practically be where we are to-day."

The forty-year mark seems to have been set by many observers as the limit beyond which fame is not likely to be gained. Oliver Wendell Holmes has been quoted as saying, "If you haven't cut your name on the door by the time you've reached forty you might just as well put up your jack-knife."

In the scientific world the critical age seems to be much lower. The scientist who has passed thirty and has made no noteworthy discovery is not likely to; and to be a world figure, one of the men whose discoveries make up scientific history, it seems necessary that something of real worth should be done before reaching twenty-five.

The points which this study will try to bring out are these: (1) that scientific genius manifests itself at an early age (usually before twenty-five, sometimes before twenty); (2) that this early work is not mere student activity, but original work of great importance and (3) that frequently it is the *most* important work of the man's career. This last point is the one of greatest interest—that so many men's names have come down to us because of the work which they did in their twenties.

In connection with this idea it can be shown that in many cases where the greatest work was not accomplished until late in life, the basic thought, or underlying *idea* of the work originated much earlier—that is, the man spent his life working out ideas which occurred to him before he reached thirty.

No claim is made that great work has not been done by men over forty. Such a claim could be too easily refuted by numerous illustrations to the contrary, but it can be said that in general the important contributions made after forty were extensions of ideas originated before that age was reached.

Galileo was eighteen when he discovered that the vibrations of the pendulum are isochronous, and within four years he had published his work on the hydrostatic balance and the center of gravity of solids. A year later, at the age of twenty-three, he evolved the laws of falling bodies. It has been said that by this discovery Galileo "probably contributed more to the physical sciences than all the philosophers who had preceded him." No mean achievement at twenty-three!

Sir Isaac Newton, "the greatest genius that ever existed," born in 1642, entered Cambridge at the age of nineteen. He promptly mastered all the mathematical works then existing, and the year before he graduated he formulated the general binomial theorem. He took his B.A. degree early in 1665 and before the end of that year had discovered the method of tangents and differential calculus, followed six months later by integral calculus. Thus, in his twenty-third and twenty-fourth years his contributions to mathematics were greater than the complete life work of any man before or since. In 1666 he began to study the action of gravity on the moon and propounded a part of his famous theory of universal gravitation. He failed to prove the theory at that time, because of an erroneous figure for the radius of the earth, then extant, but had his data been correct he might have made at the age of twenty-four, instead of some years later, the greatest contribution to science the world has ever known. He dropped the idea for several years, turning to optics and the study of light, and invented the reflecting telescope before he was twenty-six.

Newton himself said of the years 1665 and 1666, "for in those days I was in the prime of my age of invention, and minded mathematics and philosophy more than at any time since."

Huyghens, the distinguished Dutch physicist, wrote on the quadrature of the circle and ellipse at twenty-two, invented the pendulum clock in 1665 when he was twenty-six, and that same year was the first to explain the excrescences of Saturn as rings.

Mathematicians seem to be especially notable for their youthful achievements, possibly because mathematics requires no laboratory, no experimentation or elaborate collection of data on which to base its findings.

Leibnitz, codiscoverer of the calculus with Newton, first took up law and wrote many legal disquisitions of high merit between sixteen and twenty. He was eminent in history, divinity, philosophy, politics, mathematics, mining engineering and literature. His discovery of differential calculus came when he was twenty-nine years of age.

Pascal, born in 1621, was a "boy prodigy." He learned geometry surreptitiously at twelve, published at sixteen a work on the "Geometry of Conics," which contains the theorem that bears his name, and made the first computing machine at eighteen.

The famous Bernouilli family produced eight eminent mathematicians in the seventeenth and eighteenth centuries, many of whom were youthful prodigies. Nicholas Bernouilli spoke four languages at the age of eight, took his doctorate at Basel at sixteen and was full professor of mathematics at twenty-one.

D'Alembert (1717–83), French mathematician, philosopher and encyclopedist, published a scholarly treatise on integral calculus at twenty-two. His "Treatise on Dynamics" in 1743 (twenty-six years old) "marks an epoch in mechanical philosophy."[1]

Laplace (1749–1827), the greatest of French astronomers, published "Researches on Integral Calculus" before he was twenty, followed within the next four years by a series of brilliant memoirs on the theory of probability, which were the object of special commendation by the Academy of Sciences.

Leonhard Euler (1707–1783), a Swiss, one of the most prolific and versatile mathematicians of all time, received his master's degree at sixteen and wrote an essay which received a prize from the French Academy of Sciences at twenty. He was professor of physics at St. Petersburg at twenty-three and professor of higher mathematics at twenty-six.

J. L. LaGrange (1736–1813) was "pronounced the greatest mathematician living at the age of twenty-five."[2]

Karl Frederick Gauss (1777–1865), one of the most brilliant mathematicians of modern times, is said to have been able to do cube root in his head at the age of eight. He was in possession of the idea of least squares at eighteen (although he did not publish his work on this subject until 1808) and made several important mathematical discoveries before he was twenty. He published a work of far-reaching importance, "Disquisitiones Arithmeticae," when he was twenty-four.

In the field of chemistry we have many instances of epoch-making discoveries by very young geniuses. Joseph Black demonstrated the nature of carbon dioxide before he was twenty-six, reporting it in his doctor's thesis in 1754. "He is best remembered by chemists for this work," says Moore in his "History of Chemistry." Lavoisier (1743–1794), "the father of modern chemistry," was awarded a gold medal in 1766 (twenty-two years old) from the Academy of Sciences in recognition of a paper dealing with

[1] International Encyclopedia.

[2] Sedgwick and Tyler's "Short History of Science."

the problem of lighting a large town. In 1770, when he was twenty-six years old, he published the first of his many experiments on combustion which ultimately led to the overthrow of the phlogiston theory and the establishing of our modern conception of combustion.

In 1802, at the age of twenty-four, Gay-Lussac enunciated the law generally known by his name. Sir Humphry Davy was twenty years old when he discovered the physiologic properties of nitrous oxide, twenty-two when he was made professor of the Royal Institution and twenty-six when he isolated sodium and potassium electrolytically.

Michael Faraday might have been expected to be an exception to the rule that genius will manifest itself at an early age, since he was a bookbinder's apprentice with little schooling, when he entered Davy's employ at twenty-three. Yet "within two or three years he was making discoveries in both chemistry and physics which rivalled in quality those of his master."[3]

Liebig took his doctor's degree at nineteen and was full professor at Giessen at twenty-one, founding the first laboratory for chemical instruction along modern lines, and was dominating the whole field of organic chemistry within a few years. Wöhler, his close personal friend, was already widely known when he discovered aluminum at twenty-seven. He was only twenty-eight when he synthesized urea, the first instance of organic synthesis, sometimes referred to as the beginning of modern organic chemistry.

Mitscherlich, born in 1794, first studied history and philology and wrote a creditable paper on Persian history at twenty. The following year he began a course in medicine and immediately turned his attention to the study of crystalline form and its relation to chemical composition, the branch of chemistry in which his principal work was done. At twenty-five he published his brilliant paper on "Isomorphism," in which he stated the principle that "the same number of atoms combined in the same way produce the same crystalline form." Thomas Graham's studies on diffusion of gases, which led to the discovery of his famous law of diffusion, were begun at twenty-four. The first of Williamson's classic researches on the ethers was published in 1850 when he was twenty-six. Gerhardt at about sixteen "showed the natural bent of his genius by attempting a classification of the silicates which won commendation from Berzelius."

At twenty-three, Berthelot, whose fame rests largely on his work in thermo-chemistry, made the first of the direct organic syntheses by passing alcohol, acetic acid and other simple sub-

[3] Moore's "History of Chemistry."

stances through heated tubes, thus preparing benzene, phenol and naphthalene. This work and more of the same type which he published soon after gave the first great impetus to organic synthesis and set chemists to thinking about the preparation of all kinds of complex natural compounds by laboratory processes.

Bunsen, born in 1811, took his doctor's degree at Göttingen in 1830 (nineteen years old). His work on cacodyl at twenty-five was of such high class that "it alone would have assured him recognition." Dumas did some work on the chemistry of the blood at twenty-one which surpassed any work previously done on that subject, attracting the attention of Humboldt.

A striking instance of youthful achievement in chemistry is that of William Perkin, who, while a student of Hoffman's in 1856, discovered the first artificial dyestuff ever produced—"the celebrated experiment which was to give the seventeen-year-old lad immortality." He immediately left Hoffman's laboratory and entered into the commercial manufacture of the product he had discovered, overcoming practical difficulties that made the actual discovery seem a small affair, and establishing himself before he reached twenty as the founder of the coal tar color industry.

Pasteur's work at twenty-five on the relationship between the crystalline form and the optical activity of the salts of tartaric and racemic acids was of far-reaching significance. "Thus at one step Pasteur gained a place of honor among the chemists of his day."[4] Soon afterward, in studying methods for the separation of racemic mixtures, he found that the mold, penicillium glaucum, would destroy one form of crystal and not the other, and this discovery led him into other work with microorganisms which ultimately made him the greatest scientific figure of the century.

Coming down to more recent times we find that two of the basic theories of modern chemistry were formulated by young men not yet graduated from their universities. Van't Hoff in 1872 was just twenty-two when he published a pamphlet setting forth all the fundamentals of what we now know as stereochemistry, or the arrangement of atoms in space. LeBel, who formulated the same ideas independently of Van't Hoff, was himself a student at the time.

The second case was that of Arrhenius, who stated the general principles of his theory of electrolytic dissociation in his doctor's thesis when he was just completing his studies at Stockholm. It was three years later that he promulgated the theory in the form that we now know it, but the basis of the idea was set forth by him when he was only twenty-four years old.

[4] Encyclopedia Britannica.

In his "Eminent Chemists of our Time," Benjamin Harrow gives eleven biographies, choosing those chemists who have done most to influence the science during the last fifty years. Three of these, Perkin, Van't Hoff and Arrhenius, have already been shown to be shining examples of early manifestations of genius. Three others, Theodore Richards, Victor Meyer and Emil Fischer, are further examples.

Richards, whose work on the atomic weights won him the Nobel Prize in 1914, a distinction that has come to no other American chemist, started on this work before he took his doctorate at twenty. In two researches marked by novelty of procedure and extraordinary care in manipulation, he determined that the accepted atomic weights of oxygen and of copper were too high. "The boy Richards had become a force to be reckoned with."

Victor Meyer received his doctor's degree at Heidelberg at nineteen, "Summa cum laude," which is given only rarely. Within the next three years he published several important papers, and at twenty-three he announced his discovery of the nitro compounds of the aliphatic series. He was a full-fledged professor at Zurich at twenty-four. His classical work on vapor density determinations was begun before he was twenty-eight.

Emil Fischer, possibly "the foremost organic chemist of all times," according to Harrow, discovered phenyl hydrazine at twenty-three "and forged to the very front rank of organic chemists." "He belonged to the four or five leading chemists of Germany" before he reached thirty.

Two of the others cited by Harrow, Mendelejeff and Remsen, had published text-books of recognized value before they reached twenty-eight. Mendelejeff's Periodic Law was not published until 1869, but Harrow suggests that the idea of the possible relationship among the elements may have come to him through hearing Cannizarro at the Karlsruhe Congress of Chemists in 1860 when Mendelejeff was twenty-six.

Of the remaining three in Harrow's list, Madame Curie discovered radium at thirty, Henri Moissan isolated fluorine at thirty-two, followed a few years later by his other great contribution, the electric furnace, while Ramsay was the only one of the eleven whose fame was gained after forty. His work on the rare gases of the atmosphere, beginning with the discovery of argon, started in 1894 when he was forty-two. It should be added, however, that Ramsay did much valuable physico-chemical work, particularly on the thermal properties of solids and liquids, before he was thirty and that "his reputation was such that he was elected a Fellow of the Royal Society" when he was thirty-six.

Among the physicists, Carnot's epoch-making researches in the theory of heat were begun when he was twenty-three and his famous "Cycle" was published in 1824 at the age of twenty-eight; "Thus the new science of thermodynamics was born." Joule published his work on the relation of heat to mechanical force (Joule's equivalent) in 1842 when he was twenty-four; Mayer's work on the same subject was published at twenty-six; Clausius formulated the second law of thermodynamics at twenty-eight (1850).

In 1847 Helmholtz, then twenty-six years old, stated the law of the conservation of energy in "one of the most remarkable papers of the century."[5] Helmholtz had already distinguished himself at twenty-one by a thesis announcing the discovery of nerve cells in ganglia.

Lord Kelvin, then William Thomson, wrote a paper containing the germ of his theory of the age of the earth when he was eighteen, a subject which he elaborated on greatly in his later years. A paper on the motion of heat in solid bodies was favorably received by scientists while he was still an undergraduate. He graduated from Cambridge at twenty-one and made his important contributions to thermodynamics in 1848–49 in his twenty-third and twenty-fourth years.

Of the physicists who are best known for their work on light Thomas Young (1773–1829) explained in 1793 the mode in which the eye accommodates itself to distances through changes in the curve of the lens. In 1794 he was elected Fellow of the Royal Society (twenty-one years old) and in 1800 at twenty-seven he published two works containing most of his important researches. One was on the "Mechanics of the Eye," and in it he explained astigmatism, how the eye perceives color, color blindness and many other phenomena; hence he has been called the founder of the science of physiological optics. The other work on "Theory of Light and Colors" contained his researches on the interference of light, which ultimately led to the proof of the wave theory. Incidentally at fifteen Young was acquainted with Latin, Greek, Hebrew, French, Italian, Persian and Arabic, and in his later years he was a distinguished archeologist.

Fresnel put forth his proof of the undulatory theory of light in 1815 when he was twenty-seven. "No contribution to the theory of light is more important." Arago, who was associated with Fresnel in many of his later researches, was made a member of the French Academy at twenty-three, the rules as to age being suspended in his favor because of his work with Biot in the measurement of an arc of the meridian. In 1811, at twenty-five, Arago

[5] Sedgwick & Tyler's "Short History of Science."

read before the academy a paper of fundamental importance on chromatic polarization. At twenty-six he began his extraordinary course of lectures on astronomy which fascinated all Paris—both savants and public. He supported Fresnel's contributions regarding the theory of light and worked with him on several investigations.

Foucault, Fizeau and our own Michelson all contributed their work on the velocity of light before they reached thirty.

James Clerk-Maxwell (born 1830), one of the greatest of modern physicists, was very precocious. His first scientific paper "On the description of oval curves" was read for him before the Royal Society of Edinburgh before he was fifteen. He wrote two valuable papers, "On the theory of rolling curves" and "On the equilibrium of elastic solids," before he was eighteen. His great researches on electricity and magnetism began in 1856 when he was twenty-five. In 1857 he received the Adams prize from Cambridge for his paper on "The stability of motion of Saturn's rings."

Turning now to the naturalists, we find that Linneaus (1707–1778), "who established the science of botany," showed much energy in planting, collecting and observing all manner of wild growths before he was ten years old. Botany absorbed all his interest to the exclusion of his regular studies, so that at seventeen his father despaired of his studying for the university and wished to apprentice him to a tradesman. Fortunately, a physician in the town recognized Linneaus's ability "and had the rare experience of bringing a young man to his life work; and this circumstance illustrates most strikingly the wisdom of directing the young mind into its natural channels."[6] At twenty-two Linneaus wrote on the sexes of plants and at twenty-eight published his famous "Systema Naturae" which went through twelve editions, followed before he was thirty by several more of his greatest works.

Geoffrey St. Hillaire (1772–1844) was only twenty-one years old when he became professor of vertebrate zoology in the Museum of Paris. Cuvier (1769–1832), "founder of the science of comparative anatomy," was recognized as a genius at twenty-five and was made an original member of the institute on its organization in 1795. At twenty-nine he published the first classification of animals on which so much of his fame rests.

Alexander Von Humboldt (1769–1859) made his first important publication on geology at twenty. He was made superintendent of mines of Bayreuth at twenty-two because of his essays on the cryptogamous plants of the mines. He made numerous notable contributions to science in chemistry, physics and geology before he reached thirty.

[6] International Encyclopedia.

Thomas Huxley (1825–1895) graduated as medalist of the University of London in 1846. His research on "The anatomy of the Medusae," published before he was twenty-five, "placed the author in the first rank of biologists" and "stands as the basis of modern philosophical zoology." He was elected fellow of the Royal Society at twenty-six and given its medal the following year.

Sir Charles Lyell (1797–1875), eminent contributor to geological science, studied law and was admitted to the bar at twenty-six, but while pursuing his professional duties he was a frequent contributor to the Geological and Linnean Societies of London. The value of this work was recognized by Cuvier, Helmholtz and others, and he was elected a fellow of the Royal Society at twenty-nine. His great work, "Principles of Geology," published when he was thirty-three, marked an epoch in geological science and ranks with Darwin's "Origin of Species" in affecting the thought of the nineteenth century.

Louis Agassiz (1807–1873) at nineteen prepared a description of Spix's collection of Brazilian fishes which attracted the attention of Cuvier. Agassiz's work on the theory of glacier formation was propounded before he reached thirty.

Johannes Müller (1801–1858), the most masterful, accurate and influential physiologist of his time, wrote a prize essay on the "Respiration of the Foetus" at twenty, an important research in specific nerve energies at twenty-five and his colossal work on general pathology at twenty-eight.

Theodore Schwann (1810–1882), physiologist and histologist, discovered pepsin at twenty-five and contributed his most important achievement, the foundation of the modern cellular theory, at twenty-nine. The Swiss botanist Karl Naegeli (1817–1891), one of the greatest names in the history of botany, published the most striking of his many and varied discoveries in his *Zeitschrift für Wissenschaftliche Botanik* in 1844–1846 (twenty-seven to twenty-nine years old). These discoveries related to cells and cell formation and to plant protoplasm.

The point which has been referred to before, that many men who gave final formulation to their greatest work late in life had the idea much earlier, is well illustrated in the case of Darwin. He published the "Origin of Species" when he was fifty, but the idea of the theory of natural selection came to him twenty-four years earlier while he was in the Galapagos Islands during the famous trip of the *Beagle*.

One of our newest branches of science, radio-activity, may be said to have been founded by Madame Curie when she discovered radium and polonium at thirty. The work of Rutherford on the

radio-activity of thorium in 1900 when he was twenty-nine was of far-reaching importance. Soddy, who was associated with Rutherford on some of his further researches on thorium, was twenty-five when this work was published.

Of Moseley's studies of the X-rays derived from different sources which led to his discovery of the atomic numbers in 1913, Professor Millikan says, "In a research which is destined to rank as one of the dozen most brilliant in conception, skilful in execution and illuminating in results in the history of science, a young man but twenty-six years old threw open the windows through which we can now glimpse the subatomic world." Moseley was killed in the war at twenty-seven.

While inventors can not strictly be classed as scientists, it may not be out of place to close with a list of those who have earned the right to fame in their twenties.

James Watt started his work on the steam engine at twenty-four, completing it at twenty-eight; Eli Whitney patented the cotton gin when he was twenty-eight; McCormick the reaper at twenty-two; Howe the sewing machine at twenty-six. Edison was twenty-six when he invented his system of multiple telegraphy and twenty-nine when he brought out the phonograph. Bell patented the telephone at twenty-nine; Brush his dynamo-electric machine at twenty-six and the arc light at twenty-seven; Westinghouse the air brake at twenty-two. Hall's process which made the manufacture of aluminum a commercial success was patented at twenty-three.

Wells, Morton and Long, each of whom claims priority in the discovery of the use of anesthetics for surgery, were all under thirty when their work in this field was completed.

In collecting the facts for this article it has been necessary in the majority of cases to take the date of publication as the time when the work was done. This may be misleading, particularly where a man published a number of researches in a single treatise, since it is obvious that some of these researches must have been completed considerably earlier than the publication date. Even the most detailed biographies frequently fail to fix the time when an important piece of work was accomplished.

Throughout this study the writer has been impressed by the number of young scientists whose work has been influenced by some teacher or other person who encouraged and directed the youthful enthusiasm. "His work attracted the attention of so-and-so." "At the university he came under the influence of the great so-and-so." "His father early recognized and fostered his ability." "To Professor —— must be given much of the credit for his interest in the science." These and similar phrases occur

with noticeable regularity in the encyclopedias and biographical works from which the data for this article have been gained. It must follow that the opposite is true, that many early enthusiasms have been killed and many an incipient discovery blanketed through indifference or discouragement on the part of some educator.

We hear on all sides criticism of the prominence of athletics in our university life, but it may be that the educational side might take a leaf from the methods of the directors of athletics. Under the intensive athletic training in the American colleges no athletic talent escapes. Not only is the evident athlete encouraged; incipient prowess is fostered and latent ability is brought to the surface and developed. No opportunity for arousing enthusiasm by example is lost sight of. The visit of Nurmi, the Finnish distance runner, is made the occasion for increased interest in this branch of athletics and as a consequence new champions will be developed and new records set.

Was the visit of Einstein (who by the way propounded his theory of relativity at twenty-six) taken advantage of by our educators to increase the interest and arouse the enthusiasm of our students of pure science?

QUACKS AND QUACKERIES

By Dr. J. HEYWARD GIBBES
COLUMBIA, S. C.

THE term "quack" seems to have been introduced into our language by the duck. But the sound itself could not have given it recognition. It was the loudness and the meaninglessness of the duck's utterances that we have accepted as the crying of worthless wares, the pretending to virtues that do not exist and the professing of deeds that can not be accomplished. Originally the term, as applied to medical fakirs, was "quacksalver," indicating one who was a charlatan in matters pertaining to salves or remedies. It must have been thought necessary, in the beginning, to differentiate the medical quack from all the other varieties of quacks—religious quacks, literary quacks and philosophical quacks. But the irregular practice of the healing art seems to have proved so profitable that the numbers engaged in it became so great as to effectively obscure the quacks of other professions, with the result that the term has now come to mean, almost specifically, one who professes to cure the sick by means that differ from the generally recognized medical procedures, or one who lays claim to esoteric knowledge which is to be magnanimously used but not imparted.

The relatively high scientific plane that has been reached by modern medicine is so far above the humble origin of this art as to require a magnifying glass, or at least close discernment, to bring out the resemblance between parent and offspring. The truly marvelous advances of science, especially in the fields of chemistry, physics and biology, nearly all of which have found their application to practical medicine, have lifted medicine far away from its early companions, mysticism and magic. But it is useful for us to look back upon the early priest who cast out the demons of disease with incantations, charms and spells, the compounders of mummy pills and the hardy prescribers of theriac. Nor should we lose sight of the fantastic theories of disease that were entertained by our lineal, and, in many cases, respected forebears. Pythagoras's doctrine of mystic numbers, Galen's weird ideas of anatomy and physiology, and the polypharmacy of the recent past should all serve to curb our arrogance and keep us humble. Virtue does not exist without vice; the one is dependent for its existence upon the other, and it is well to keep the com-

plemental relationship in mind in attempting to form our estimate of good and bad. In THE SCIENTIFIC MONTHLY for March, 1923, the following appeared under the title of "The ancestral scandals of science":

Tracing back the history of a science is like searching out a genealogy; one is sure to unearth something scandalous if he goes back far enough. John G. Saxe warned the would-be ancestor worshipper of this danger in the following lines:

Depend upon it, my snobbish friend,
Your family thread you can't ascend,
Without good reason to apprehend
You may find it waxed at the farther end
By some plebeian vocation!
Or, worse than that, your boasted line
May end in a loop of a stronger twine,
That plagued some worthy relation.

The chemist handles with reverent awe the latest unearthed and earliest written text of his science, a scrap of Egyptian papyrus, but when he gets it translated he finds it is a counterfeiter's receipt, a method of making base metals look like gold. Or else it is a receipt for a cosmetic, which is also a form of counterfeiting.

The astronomer finds in a Babylonian brick the first record of the stars but discovers to his disgust that the cuneiform inscription is an astrological treatise, a fortune-teller's handbook.

Hero of Alexandria described the turbine steam-engine, the coin-in-a-slot machine and other valuable inventions. But what were they invented for? So the priests of the temple of Isis could perform fake miracles.

Pythagoras discovered the law of hypotenuse—and was so happy over it that he killed a hundred oxen. It is hard for us to see why. But mathematics was to him a form of magic, otherwise he would not have been interested in it.

Paracelsus did much to advance medicine. We can not yet dispense with the three drugs he introduced, mercury, opium and antimony. But Paracelsus's real name was Bombast—and he lived up to it.

It is humiliating to confess, but the progress of science in its early days owed much to the false pretensions of its practitioners. Kings would not have kept a corps of men studying the stars unless they had proffered practical returns in the way of auguries. Chemists were subsidized for centuries because they promised the philosopher's stone and the elixir of life—promises not yet fulfilled.

Columbus would not have ventured to cross the Atlantic if he had not been wrong in his figuring about the size of the earth, and his royal backers would not have put up the money for the voyage if he had not told them wrongly that he could reach India that way.

Ponce de Leon was led to Florida by his search for a mythical Fountain of Youth. Coronado explored the Kansas plains to find the fabulous Seven Cities of Cibola. The vain search for the impracticable Northwest Passage to Asia was the stimulus to exploration for a century.

Fortunately for the world, fictitious aims may lead to real results. The scientist has learned to achieve greater miracles than he ever pretended to perform. Truth has grown up under the shadow of error as infant oaks get their start under the shelter of worthless weeds. In chasing a will-o-the-wisp, one may catch sight of a fixed star. Falsity has often served as a guide to Truth.

With these thoughts before us we might approach the subject of quackery in general with a very tolerant attitude, and at least an inquiring spirit. There is too much success in such practice to make it unworthy of thoughtful consideration, and we are all too prone to sacrifice this kind of consideration to prejudice and resentment. There can be no doubt but that there have been quacks who were sincere in their professions, and, in such cases, they have been guilty of nothing more than an error (not an uncommon fault); fanatical zeal doubtless has something to commend it; malicious misrepresentation, nothing. Intolerance and resentment on the part of the regular medical profession toward quacks have never done them harm. The layman looks upon such conduct by the physician as an expression of his chagrin at the encroachment into his field of a newcomer, and the quack is likely to profit by, rather than suffer from, attacks that are made upon him from this quarter.

There is much of interest in the history of quackery. Some of these men have been endowed with dynamic personalities, the type that are the "observed of all observers," and who put it across with little more than this. Some have been highly educated, if attendance upon universities can be accepted as a standard; while others have seemed to succeed through the sheer force of their ignorance. In addition to the interest which this subject holds for us, there is amusement and pathos in it.

There seem to be two main avenues through which quackery finds access to human credulity. It is either through the claim of a divinely inspired personality or the development of a doctrine concerning the cause and cure of disease which differs radically from the commonly accepted ideas, the doctrine being surrounded with words and phrases which have a euphonious sound and little meaning. The personally inspired healers find their anchorage in the religious beliefs and traditions of all ages; for, in primitive society, as well as in our supposedly advanced civilization, the incarnate gods, or even the secular representatives of the gods, have had healing powers and practices attributed to them. The average person seems to think that this is too good a chance to pass up, and when some one announces that divine guidance has been received, or instruction given for the cure of the sick, the sufferers are in turn inspired with hope, and they come in flocks for assistance. These claims are not always the product of cupidity; in fact, the success which attends them often depends upon the fanatical sincerity of the testifier. The substantial changes in the national life of France which were brought about by the hallucinations and delusions of Joan of Arc serve to illustrate the peculiar

appeal and impelling force of these phenomena. But quacks who enter by this approach most often have a rapid rise, a brief period of glory and an equally rapid descent. Their appeal is entirely to human emotion, a flimsy ground which soon gives way under them.

The more or less organized systems of quackery which have been evolved from time to time have usually been developed from a fanciful variation of commonly accepted knowledge. Germs of psychological truths have been magnified into distorted doctrines of the cause and cure of disease, electrical phenomena have stimulated the imagination to weird ideas in connection with its application to the seeking after health, a smattering of anatomy has led to peculiar generalizations, and misinformation concerning the use of drugs has resulted in the appearance of systems that are drugless, drugful and homeopathic. Here we have the development of so-called cults, sects, etc.; and they endure in spite of demonstrated error. Why they should is somewhat difficult to understand. The only explanation immediately apparent is the germ of truth and the cloak of words, words, words. These are the practices which so often arouse our wonder at the gullibility of mankind, and not infrequently make us resentful at the impositions which are practiced. But we should keep in mind that, even here, sincerity seems to be the rule rather than the exception in the founders of these cults. In most instances, brooding or hysterical individuals, reacting against the deficiencies of regular medicine, or having *experiences* which appeal to them as revelations, enthusiastically launch their ideas, and they find a sympathetic reception in the minds of other brooding and hysterical people who have suffered from the failures of doctors or medicine. On the other hand, we shall find instances of undoubted malicious exploitation.

There is an abundance of literature dealing with the lives and practices of the individual quacks of the past. Space will not permit of a detailed review of this fascinating subject. We shall just touch the high spots sufficiently to indicate the forms of weirdness in ideas that have successfully imposed upon mankind's gullibility.

It is questionable as to whether we should class the practices of the primitive priest, the incantations, the amulets and charms, the mystic dances and other rites which were employed for expelling the demons of disease from the human body as quackery. It is almost certain that these ancient magicians, the forerunners of our doctors and ministers, believed as firmly in the efficacy and propriety of their acts as their successors do in theirs to-day. The hepatologist and other prognosticators of ancient times are doubtless entitled to equally considerate treatment. We may not agree

entirely, but there is much to be said in favor of the idea that "there is nothing either good or bad but thinking makes it so," and it is probable that these early seers were using the best information at their command.

The astrologers, crystal gazers, alchemists and others of like ilk bring a doubt into our minds as to whether they are deserving of leniency. Their parasitic attachment to royalty, their high position at court, their material well-being and their oracular utterances make us wonder if they were not playing on the kings like fiddles and marking time with their practices on the lesser peoples.

The power of personal healing has always been conceded to be a godly attribute, and the idea has held throughout the ages that the gods might delegate this power to their chosen representatives. It is through this means that the kings of France and England derived their rights to touch their subjects for the cure of disease. Here we have a long list of royal quacks. Philip I of France (1061–1108) is our first authentic record of the royal charlatan, with Edward the Confessor (1066)—inaugurating the custom in England, and Queen Anne and the Stuarts having the hardihood to carry the custom into early modern times. Thus, our quack might be said to keep good company.

Valentine Greatrakes asked no odds of royalty and achieved equal success with the best of kings in curing disease by the simple laying on of hands. He claimed that he received his commission as a healer directly from high heaven through dreams that came to him on three successive nights. He must have had no more earnest conviction of his power than did many people of his time, for he cured them by the thousands.

Cagliostro presents himself as one about whom we might say little that is good. He it was who in the middle of the eighteenth century put magic to profit, discovered hidden treasures for gain, developed forgery as a fine art, sold the virtue of his wife to add to his chest of treasure and healed the sick of Europe by mystic means. He is the one character of whom I have read that seems deserving of the gentle offices of the Roman inquisition. It is not displeasing to know that he died in prison following sentence from this court.

The subject of "Magnetic Cures" owes much to Professor Maximillian Hell, of Vienna, whose astronomical observations were interrupted by the electrical sparks that were drawn from the heavens by Benjamin Franklin's kite. The good professor theorized that magnetic forces might have the power to pull diseased parts straight, and the practical application of his ideas resulted in making the lame walk. Here a germ of truth, the magnetized

metal, was combined with professorial suggestion, and the era of magnetic cures began.

Friedrich Anton Mesmer, the Austrian physician, may be regarded as one of the most interesting quacks of all time. In fact, there is room for doubt as to whether he should be spoken of unqualifiedly as a quack. He was a man of excellent general education, and received his medical training at Vienna under such masters as Van Swieten. He became interested in astronomy early in his career, and had strong leanings toward mysticism. He serves as an excellent illustration of the type of man who thinks too much and observes too little. With the advent of electricity, he, like Professor Hell, connected it with his astronomical notions, and, because of the supposed relation of the stars to the lives of men, inferred that it could be turned to use in the cure of disease. Magnets appealed to him as the tangible means of bringing about its application, and his methods met with gratifying success. It was not until he came in contact with the good priest, Gassner, a German clergyman who had demonstrated the efficacy of clerical suggestion in curing disease, that he learned that similar results could be obtained by personal contact without the intermediary aid of material magnets. But magnetic force had formed the basis of his original conception, and he could not relinquish the idea. So he proceeded to evolve an elaborate system of words and ideas to prove that magnetic force was an inherent quality of human flesh, and that the interaction of one personality on another could be made to bring about desired results. Here we have an example of the *doctrines* that have been built up by these queer and freakish thinkers, the revival of the doctrine of animal magnetism. Its author rapidly persuaded himself and others that his personality was endowed with a lion's share of this mystic quality and that he was peculiarly equipped to influence the destinies of other people. There is every indication that Mesmer entered upon the elaboration of his notions with earnestness and sincerity. But it is more than equally certain that the material success which attended his efforts soon led him into the grossest kind of commercial charlatanism. His temple in Paris was sumptuously furnished, varicolored lights were employed to maximum effect, soothing strains of music were continuously in the air, the atmosphere was charged with burning incense and the great healer enhanced the natural magnetism of his body with rich and mystic robes. Controversies raged around him, the medical profession arrayed itself against him, excitement took possession of Paris and extended to distant parts, and the human magnet attracted to itself the lesser human magnets and a greater part of human wealth. After a few years of unprece-

dented power he was literally forced out of Paris with opprobrium and stamped with the epithet of imposter; but it is highly probable that he had developed a convenient cynicism that permitted of the enjoyment of his gains.

Phineas Quimby, one of America's most noted exponents of magnetism as a panacea, holds an interest for us in that there is good reason to believe that he played no little part in directing Mrs. Eddy's thought into the channels that finally emptied themselves of Christian Science slush. This good doctor relied entirely upon animal magnetism or hypnotism in his ministrations, and it is said that his cures were as marvelous as could be desired. As will be seen later, Mrs. Eddy had already proved herself to be a suitable subject for suggestion as a means of producing or curing disease when she consulted Dr. Quimby as a means for relief from "spinal nervousness." She had fallen on the ice in New Hampshire, doubtless landing in the conventional position, and had sustained a disability which in these times is almost specifically produced by street-cars, railroad trains or other corporation agencies. Physicians and surgeons had failed to relieve her, but Dr. Quimby's soothing words and manual rubbings brought her to what she said was "better health than I before enjoyed."

Spiritualism may be looked upon as an offshoot of the doctrine of magnetism, the influence of magnetic personalities simply being extended into the spirit world. As is well known, this movement originated in America, in the home of the Fox sisters of New York, where supposedly unexplainable rappings were given intelligible meaning, and contact with the spirit world established. This led to the day of mediums, peculiarly endowed personalities who, in trance states, did all that one could wish in establishing a liaison between the here and the hereafter. Andrew Jackson Davis was a notorious imposter of this type, but his cures were no less effective than his proceeds handsome. This movement was conceived in fraud, as was afterwards confessed by the Fox family, but Sir William Crookes, Sir Oliver Lodge, Sir Conan Doyle and other "intellectuals" seem to be of the same opinion still. Harsh words rush to mind when men of this type, representatives of science, learning and station, fall for such fanciful notions, but let us be content with repeating that "sweetest things turn sourest by their deeds, lilies that fester smell far worse than weeds."

Christian Science, spoken of as the bastard child of a pseudo-science and an unholy religion, owes its inception to the reactive phenomena of an hysterical disposition. Mary Baker was born and reared in enlightened and refined surroundings, and she attracted attention in childhood by her precocious thinking about

religious matters. The idea of predestination seemed to have oppressed her by its hopelessness, and she cast about for ways out of the difficulty. In early life she suffered from a fever which subsided shortly after she had prayed for relief under the instruction of her mother. This episode deeply impressed her, and assumed even deeper importance upon retrospect when, in later life, she connected it with other *experiences*. Her deliverance came when, in 1866, at 45 years of age, she obtained relief from spinal nervousness through the ministrations of Phineas Quimby and the fervor of her prayers. She says that the experience brought her to "the scientific certainty that all causation was mind." Predestination became impossible when God was demonstrated to have an appeal-reaching nature, a sympathetic ear to human suffering, and a willingness to change his mind, to substitute health for ill health upon request. With fanatical generosity she proceeded to share her discovery with others, and her enthusiasm and undoubted sincerity, combined with her ability to dress her ideas in pious and semi-scriptural phrases, succeeded in establishing an absurd system of philosophy and healing so firmly that a considerable portion of mankind seems destined to follow it forever. It is useless to point out the errors and inconsistencies of Christian Science to properly balanced minds, but it is interesting to remember that "cures" in infinite number have been effected by it; the fact that many real cures have been prevented by it is certainly of less interest, if of more importance.

John Alexander Dowie was a canny Scot who found a fertile field for his pretensions as a personal healer in America. He, too, combined variety in religious thinking with suggestion in the cure of disease. He proclaimed himself to be "Elijah the Restorer," and great numbers were gladly restored by him. He built churches and cities with the proceeds from his cures, and reigned as dictator among his citizens, imposing upon their civic liberties as well as upon their freedom of thought. But great was his fall, for he was finally expelled from his own church and city on charges of fraud, tyranny and polygamous tendencies.

Hahnemann's homeopathy is just now taking its last dying gasps after more than 125 years of imposing its absurdities upon mankind. But it, too, has had its cures by thousands, and, in spite of the pedantry and falsity of its doctrines, it doubtless saved many poor patients a nauseous dose of medicine at the hands of the regular physicians. It is supposed that Hahnemann was stimulated to his work by the promiscuous drugging which was generally practiced in the treatment of disease, and his millionth part of the common doses was doubtless a great boon to patients. His plagiarized

slogan, "similia similibus curantur," his provings, potentizings and dynamizing of drugs and his other weird words and phrases seem to have successfully mystified the human mind, and were doubtless important factors in the efficacy of his treatments. Even such satire as Bishop Doane's did not laugh it out of court:

> Stir the mixture well
> Lest it prove inferior;
> Then put half a drop
> Into Lake Superior.
>
> Every other day
> Take a drop in water.
> You'll be better soon,
> Or at least you oughter.

F. Matthias Alexander, of Australia, is to be mentioned in passing because his system of physical and mental culture has proved such a boon to the trained minds of university professors. Walsh gives some extremely amusing testimonials from college professors concerning this quack. He quotes one of the professors as follows:

> He does not have to undress you or ask you what is the matter with you, or establish your anamnesis. Your obviously faulty posture and movements immediately strike his keen, experienced eye. He sees the beginnings of cancer, appendicitis, bronchitis, tuberculosis, etc.

Walsh also says that the "Introductory word to this work in which appendicitis, cancer, tuberculosis, etc., are cured by means of breathing exercises and 'conscious control' of the muscles, was written by one of the best educated professors in this country who is the head of the department of philosophy of one of our most important universities." God! What a travesty on the word philosophy.

In connection with the easy mark which is often afforded by learned men for quacks, Bishop Berkeley presents an amusing picture of such a man. He devised a cure of his own, and magnanimously gave it to his fellow-man. This philosopher, religious worker and missionary among the American Indians discovered the versatile healing power of tar water. He simply mixed a gallon of water with a quart of tar, allowed it to stand for forty-eight hours, and poured off the supernatant fluid, thus obtaining a remedy which he recommended for "gout and fever, coughs, pleurisy, peripneumony, errysipelas, asthmas, whether it come from the heart or kidneys, indigestion, hysterics, mortification, scurvy, and liver diseases." We might be thankful that the clergy have given up some of their former tendency to cure the body, and we might hope that their efforts to save the soul are based on somewhat more rational grounds.

Andrew Taylor Still has been credited with sincerity in his founding of the cult of osteopathy. He was a fairly well-educated man, a physician and one who devoted much of his spare time to the observing of plants and animals. It would seem that he was thrown off of a level footing, in the mental sense, by the death of three of his children from spinal meningitis and was led to search for some new method for the cure of disease. Osteopathy was the product of his musings. Nothing could be more irrational than the ideas around which this cult was built, but it worked and is still working. The suspicion of cupidity in the founder is aroused by his own statement that he had been accused of being crazy by his clerical brother, but that he later won him over when he demonstrated that "there was money in it."

Chiropractic is of too recent origin to demand much comment. B. J. Palmer, D.C., Ph.C., the founder and propagator of the cult, states that the first chiropractic adjustments were given by his father, D. D. Palmer, in 1895. Since then innumerable spines have been adjusted and cures wrought, as witness the testimony before our legislatures. Until very recently chiropractic concerned itself entirely with the matter of cures, this being a common trait of practically all quack systems, but in the past year the fertile brain of Palmer has devised an instrument, the neurocalometer, which makes diagnosis easy and mechanically accurate, pointing out unerringly the nerves that have their vital capacities interfered with by pressure. It is estimated that this new discovery will net Palmer a great deal of money from his disciples, a direct tax which will unfortunately be passed on to the gullible public.

Albert Abrams was a queer freak. He must have been a manic type with an overactive and superficial mind. He received an excellent medical education, and seems to have done well enough in the practice of medicine for a time. But a cerebral switch was left open, and his mental machinery ran off the track. This freak differed from the others in that diagnosis was given a prominent place in his system. It is charitable to think that this deviation from the custom of the usual quack may have been responsible for so many of the regular medical profession swallowing Abrams's bait, hook, line and sinker. It seems to have mattered as little to them, as to the poor seekers after health, that he coined unintelligible words and that his writings evidenced gross misunderstanding of such terms as watts, ohms, amperes and volts. It is rather surprising that this scheme should have begun to wane so soon.

Walsh, in his very entertaining book on cures, classes Freud and psychoanalysis along with the type of quack of whom we have been treating. There is doubtless much to be said in favor of this

idea, and the probabilities are that as time goes on we shall recognize more complexity in Freud's expressions than truth in the complexes which he purports to describe. Certainly his cures have been forthcoming, but with equal certainty a tremendous amount of mental obfuscation has resulted.

In this day of patented medicines, we should not fail to mention the successes which have attended similar agencies in the past. Weapon ointment had much to commend it. The salve was applied to the weapon which had inflicted the wound, and the wounded was spared meddlesome and painful handling. Not even this backhanded compliment can be paid to most of the others. Theriac, the preparation which contained sixty-four ingredients, tar water, mummy pills, rattle-snake poison and countless other buncombes have proved as efficacious as have tanlac, Lydia Pinkham's Vegetable Compound, Peruna and Doan's Kidney Pills. It was the success of these remedies which caused Lowell to exclaim, "What is the need for an Aladdin's lamp when palaces can be built out of patented pills?"

Treatment vs. Diagnosis

Sentient beings must pay the penalty of pain for pleasure. The capacity to experience the latter carries with it the necessity for feeling the former. So we might say that suffering entered the world with consciousness. With the advent of thought means for the relief of suffering were immediately sought. As some one has said, it is an inherent instinct in man to believe that relief from suffering is an attainable goal. Consequently, the attention of all mankind is readily attracted by subjects that deal with the preservation and restoration of health, but especially with deliverance from discomfort. However, it is interesting to observe how lacking in the inquiring spirit this interest is. In this subject, of all others, we seem to be intensely practical, caring for nothing but results, and wishing, even, not to be bothered with the whys and wherefores of our cures' success. A sick man may be likened to a landlubber on a disabled ship at sea; he cares little for the technical skill, or lack of it, with which the sails are manipulated. It is any port in a storm for him, and any means of getting there. A physician, looking sufficiently far ahead to recognize the greater usefulness of proper thinking, might approve Dr. Halsted's statement that he would rather be wrong with a reason than right without one, but it is easy to understand that the patient would strongly subscribe to the contrary view. Thus it is that empirical methods for the cure of disease have taken little heed of the matter of diagnosis, or of determining the underlying cause of the patient's trou-

ble. They go directly to the fountain head of human interest—*cures*. Their discoveries are good for all troubles, so why should they concern themselves with differentiating different kinds of trouble? This train of thought certainly seems to meet the demands of the situation, for "age has not withered it, nor custom staled its infinite variety." Abrams proved himself the outstanding exception to this rule. He at least went through the motion of making a diagnosis, and this may have had no little to do with the relatively brief duration of his fantasy. But his cure was omniscient, the specific electrical vibrations all came out of the same machine, adjusting themselves to the peculiar needs of the individual and dispensing "ohms" with a selective intelligence. This should have been general enough to obscure specific thought. But they turned it down! And, why do you suppose? Consider, and see if you do not think that it was due to the effort to introduce a quack system for the *investigation of disease*. This idea of diagnosing syphilis, cancer and tuberculosis from a drop of blood that had traveled thousands of miles was too enticing a thought to escape the attention of well people, and they think a little straighter about health and disease than do those who are sick. Abrams' effort will doubtless serve a good purpose in that a long time will elapse before diagnosis is again given a prominent place in association with new cures.

Effectiveness of Quacks

The effectiveness of quacks, considering for the moment only those conditions which they themselves create, doubtless results, mainly, from the following causes:

(1) A dominant personality in the healer. These people are most often of a forceful type, frequently with a brazen air and a rhinoceros hide, and their fervor of fanaticism or greed permits them to put an enthusiasm into their movements that inevitably sweeps the suggestible part of their fellow-men with them. It is important to bear in mind that, in most instances, the originators of the different cults are actuated by a sincere belief that they have found something that is of real value. They fall into that group who know not and know not they know not. This combination of confidence and blindness gives them a stirring urge to spread their new gospel.

(2) The verbal dress in which they clothe their thoughts is high-sounding and seems to be effective. It is very difficult to understand how the words and phrases that have been created by these impostors could fool intelligent persons, but we have seen that professors, clergymen and physicians all fall for them. Volumes have

been written about one word in the battle-cry of homeopathy, an apparently earnest effort to determine whether Hahnemann intended to vary the dictum of Paracelsus to the extent of changing an "a" to an "e" in curantur. Bishop Berkeley philosophizes tar water into universal efficacy "with words of learned length and thundering sound"; Alexander satisfies our college professors that "he actually remodels the body as a sculptor models the clay, gives one a fresh and discriminating muscular sense which not only does away with distortions and expensive strains, but reacts upon one's habitual moods and intellectual operations"; and practically all the others have mystifying words surrounding their practices. Two authorized definitions of healing sects will serve to illustrate this point. The first is the definition of natureopathy appearing in the statute books of the state of Connecticut. It is as follows:

> For the purposes of this act, the practice of Natureopathy shall be held to mean the practice of the psychological, mechanical and material sciences as follows: The psychological sciences such as psycho-therapy; the mechanical sciences such as mechano-therapy, articular manipulations, massage, corrective and orthopaedic gymnastics, neuro-therapy, photo-therapy, hydro-therapy, electro-therapy, thermo-therapy, physio-therapy, chromo-therapy, vibro-therapy, concussion, pneumate-therapy and zono-therapy; and the material sciences such as dietetics, histilo-therapy and external application.

They might have included under the material sciences the license to extract shekels.

The nimble-witted Dr. Palmer speaks of chiropractic in the following terms:

> Chiropractic is a name given to the study and application of a universal philosophy of biology, theology, theosophy, health, disease, death, the science of the cause of disease and the art of permitting the restoration of the triune relationship between all attributes necessary to normal composite forms; to harmonious quantities and equalities by placing in juxtaposition the abnormal concrete positions of definite mechanical portions with each other, by hand; thus correcting all subluxations of the spine, atlas to coccyx inclusive, for the purpose of permitting the recreation of all normal cyclic currents, through nerves, that were formerly not permitted to be transmitted, through impingement, but have now assumed their normal size and capacity for conduction as they emanate through the intervertebral foramina—the expressions of which were formerly excessive or partial lacking—named disease.

It must take a man of ingenuity to use so many words and fail to make sense out of them. However, these expressions seem to satisfy the minds and cure the bodies of our citizens in this, the twentieth century.

(3) The disciples of the master quack, as well as the masters themselves, after they have tasted of material success, stoop to cheaper means in selling themselves and their wares to the credulous public. Lurid testimonials of cures that have been accomplished, newspaper advertisements of an enticing nature, impressive de-

meanors and all tricks of the trade are carefully studied, and the whole used to the best advantage.

(4) The quack not infrequently becomes the dupe of his own pretensions, and his successful handling of suggestible subjects too often persuades him that he has been chosen by God to deliver mankind from the bondage of disease. When this change of personality comes, and the retrospective falsifications of memory follow, his power as a healer is greatly enhanced, and his arrogance and assurance proceed hand in hand.

Receptiveness of the Public

The success of any human endeavor depends upon human receptiveness to it. The above review and our daily observations show plainly enough that people of all times are peculiarly receptive to any idea relating to the cure of disease. It is interesting to inquire as to why this is true.

In the main, the situation may be summed up by the statement that when the sickness comes in the judgment flies out. Introspection and subjective thought are notoriously productive of unsound reasoning, and physical disability is immediately productive of this type of thought. Even trained physicians do not escape its ravages. All of us have had minor illnesses which have received from us the gravest interpretations. And the more we think under such conditions, the further wrong we are likely to go. In contrast to learning, too much thinking about such matters is a dangerous thing, for thinking, as well as conscience, is prone to make cowards of us all.

The fallacies resulting from this type of thinking are typical examples of Bacon's "idols of the cave." In this state of mind mankind may be depended upon to be consistently illogical and is an easy target for any suggestion that may be aimed at him. Hippocrates recognized this fact in his aphorism to the effect that nature cures the disease while the remedy amuses the patient, and Oliver Wendell Holmes expresses the idea in his own inimitable fashion as follows:

> There is nothing men will not do, there is nothing they have not done, to recover their health and save their lives. They have submitted to be half-drowned in water, and half-choked with gases, to be buried up to their chins in earth, to be seared with hot irons like galley-slaves, to be crimped with knives like cod-fish, to have needles thrust into their flesh, and bon-fires kindled on their skin, to swallow all sorts of abominations, and to pay for all this, as if to be singed and scalded were a costly privilege, as if blisters were a blessing, and leeches a luxury.

In addition to this general consideration, there are two specific ones that tend for something more than simple receptiveness on the part of those who patronize medical fakirs. The partisan attitude

of these patrons is a striking phenomenon. It is not uncommon to find some of our better citizens, not content with availing themselves of the services of the quack, but urging others to do so and busying themselves to bring about a legal recognition of the new system of healing. The probable explanation of these activities is that these worthy citizens feel the necessity for justifying their departure from the commonly accepted ideas of society relating to the cure of disease. They are conscious of the need for defense, and their defense reaction leads to aggressiveness. Again, the custom of practically all quacks to demand payment in advance of treatment tends strongly to the success of their ministrations, for no man likes to admit that he is stung, and he has more than a common interest in the success of his venture when his money is in it.

Deficiencies of the Regular Profession

The regular medical profession has contributed its full share to the success of quackery. There are some general indictments that might fairly be levelled at us. We have too often let our theories outrun facts, we have taken up fads and isms with the best of them, we have supplanted common-sense with doctrines, we have put pomp and circumstance above substantial scientific attainment, and we have let our cures make us arrogant: there is almost no practice among those that we are pleased to call quacks that has not its parallel in the activities of our own brethren. Dr. Mayo gave thanks that medical science had advanced to the point where the physician could perform his functions in a sack suit, discarding the added embellishments of a long coat and high hat. But these adornments are still figuratively with some of us in manner, word and action. We have high-sounding phrases, words that obscure or falsely satisfy thought, and we administer drugs and treatments with a gullible satisfaction in their efficacy or with the conscious intention of amusing the patient while nature cures the disease. As long as such practices continue we must face our responsibility in contributing to the success of the irregular practitioner.

Suggestion was long a thoroughly approved medical practice. It may be defined as the act of transferring an idea or mental state to another, irrespective of its truth. Here we are speaking of conscious or purposeful suggestion, and this is the only kind of suggestion for which we need assume responsibility. Suggestion must always play a large part in determining human conduct, but the medical profession need not stultify itself by misinterpreting the phenomena which result from it, or by subscribing any longer to the practice of telling falsehoods as a means of curing disease. But the biggest fool of all fools is the fool that fools himself, and doctors

have a peculiar susceptibility to this type of fooling. Hypnotism, the violet ray, the electronic phenomena, innumerable worthless drugs and a host of other matter could be mentioned to show how thoroughly members of the medical profession can be fooled. However, it is not being fooled that we are warring against now, but fooling. Not so very long ago I was shocked to hear a young physician, at a medical society meeting, say that doctors could not afford to be entirely honest with their patients. It is disappointing to hear a reactionary expression of this character uttered by a young man, for it brings to mind the possibility that the custom of fooling patients, the great barrier between the public and full confidence in the medical profession, is to stand for some time to come.

Ignorance among doctors is another factor for the success of quackery. In this day of thoroughness in medical education it would seem impossible that lack of information could assume a prominent rôle among us, but such is too often the case. The completion of a college course, a medical one in particular, does not produce an educated man. The simple foundation is laid upon which to build. The finishing of the structure depends upon continuous activities as a student, and, unless these constant touches be applied, the unfinished parts are likely to rot. Dr. Barker has said that the internist who sleeps for more than eight hours is apt to fall behind; and there is not good reason for admonishing only one group. On what other grounds than ignorance can we explain a medical man's advice against typhoid vaccination, his use of salol as an intestinal antiseptic, his ready prescribing of proprietary remedies or advice to a diabetic that milk may be taken in unlimited quantities? We can not blame people for rushing from such practices and seeking assistance elsewhere.

As Selden says, "no man is the wiser by his learning." There is an inherent quality of mind, the capacity to discriminate essentials from non-essentials, the faculty of estimating the value of new ideas and proposals or the ability to decide between truth and error, the great mental function of judgment that seems to be possessed by all too small a portion of mankind in general, and which does not seem to be developed by even extended efforts at education and training. Physicians show this deficiency as plainly as others. Possibly its failure in them is more striking than in other professional men, for there is a distinct tendency on the part of patients to aggrandize a physician, to ascribe to him almost supernatural qualities of information and judgment, and, when their ideas meet with disappointment, they are likely to generalize the shortcomings of the individual to the profession which he represents. A fallen idol is contemned, and the medical profession has

to pay the price of having suspicions of inefficiency directed at it in return for the very veneration which the individual doctor commonly enjoys. We should not quarrel with our fellowman for this decision; we should busy ourselves in teaching him what to expect from the medical attendant of his choosing and lead him to know that, failing to find it in one, he may safely expect it in another. In other words, the public should be taught to look to medical science for assistance and to regard the individual practitioner as the fallible servant of this great organization.

Even the conscious efforts of the medical profession to protect the public from incompetence in its own ranks and from the ravages of the irregular practitioner, have done no little to arouse a sympathetic interest in the latter. For about ten years, ending in 1873 when Texas passed the first medical practice act of this country, Dr. N. S. Davis tirelessly advocated the passing of laws which would require proper qualifications in those who were to practice medicine. Since that time every state in the Union has passed similar laws, and our medical examining boards are supposed to stand as an effective barrier between the public and inadequately equipped physicians. But, in the very nature of things, these boards are made up of physicians, and when they declare that representatives of the quack cults of one kind or another are not properly equipped for practicing the healing art, they give cause for the raising of the cry of persecution, discrimination and fear of competition. The quack and his patron use these ideas to full advantage.

Is there Deliverance from the Quack?

At first blush one is inclined to say that the quack is destined to be with us always. The instinctive desire of man to seek relief from suffering, his lack of judgment when in pain, and his ready belief in the *experience* of those who have been cured by any means whatsoever make it almost certain that irrational and even unscrupulous systems of healing will always have a vogue.

We have seen that education does not equip a man to think in a discriminating way when he is sick. Louis XI believed in his Gallioti who foretold his destinies, Queen Anne entrusted her eyes to William Read and knighted him for his frauds, George II yielded his body to the ministrations of "Spot" Ward, Napoleon consulted the pythoness Lenormand, Bishop Berkeley had an abiding faith in tar-water, Alexander preys upon the undeveloped and underused bodies of our college professors, and we frequently hear of respected citizens being cured by the osteopath, the chiropractor and the electronic wave.

The law seems powerless to stop the irregular practice of medicine. Laws we have a-plenty. But for some reason they do not

work. It is said that in some states, where chiropractic is specifically outlawed, the chiropractor does his most flourishing business. We see the quack openly defying the law, declaring its administration wrong and continuing his activities in spite of it all.

There is one hope of deliverance. Just as scientific chemistry banished alchemists from the face of the earth, medical science is capable of routing the host of imposters that are now barking at its heels. But medical science must, like chemistry, become impersonal. No one thinks to-day of a chemist as other than a student or investigator of his science; the chemist dwindles into insignificance in comparison with the colossal size and substantiality of chemistry. So the physician must be subordinated to the great subject in whose name he is working. The public's attention must be directed to medicine and its truths, not to doctors and their errors. The test of medical science is the prevention of disease. Smallpox, typhoid fever, the plague and many other diseases have had their ravages checked by the application of exact sciences, chemistry, physics and biology, which, because of the mode of their application and the purposes for which they were used, have been grouped under the collective term of medical science. It is this shrine at which we must worship. We must show the people our god, and ask them to see in us his servants, subject to error.

Still our *cures* rise to plague us. It is hard to meet with success and still be humble, and cures must fall to the lot of all physicians, for nature's inevitable tendency is toward repair. Here the humble priest must take great care lest he become a god, for, if he should, his services to the cause are lost, and he is likely to be cursed by the very power which he formerly served. The cure of disease can never be advanced to the position of exactness that is to be attained by its prevention. In many instances, physics, chemistry and biology have yielded us specific weapons with which to wage specific battles, but in many of the problems presented by suffering humanity we must still depend upon less exact means for their solution. The psychoneuroses present the greatest pitfall. Here is the serpent that tempts us away from our salvation. The difficulties here can readily discourage us; the successes can with greater readiness lead us to false conclusions and arrogance. Our protection lies in rigorous honesty, the use of persuasion rather than suggestion in the handling of these patients and a clear appreciation of psychological processes when they show themselves for good or bad. The regular practitioner must follow Polonius's advice:

> This above all: to thine ownself be true,
> And it must follow, as the night the day,
> Thou canst not then be false to any man.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

SUNSHINE FOR BRAINS

It has been known for some years that the ultra-violet rays, whether they come from the sunlight or the mercury-quartz lamp, will greatly benefit and often cure children crippled by rickets or tuberculous joints. It is now found that light treatment not only betters their bones and improves their general health, but also brightens their brains and sweetens their dispositions.

A class of boys from the London slums who were taken to the garden of a private house on Clapham Common, where they studied and played all day long, attired in "very short shorts and no shirts," showed at the end of six weeks that even such feeble sunlight as London affords had increased their mental capacity and alertness as well as their appetites.

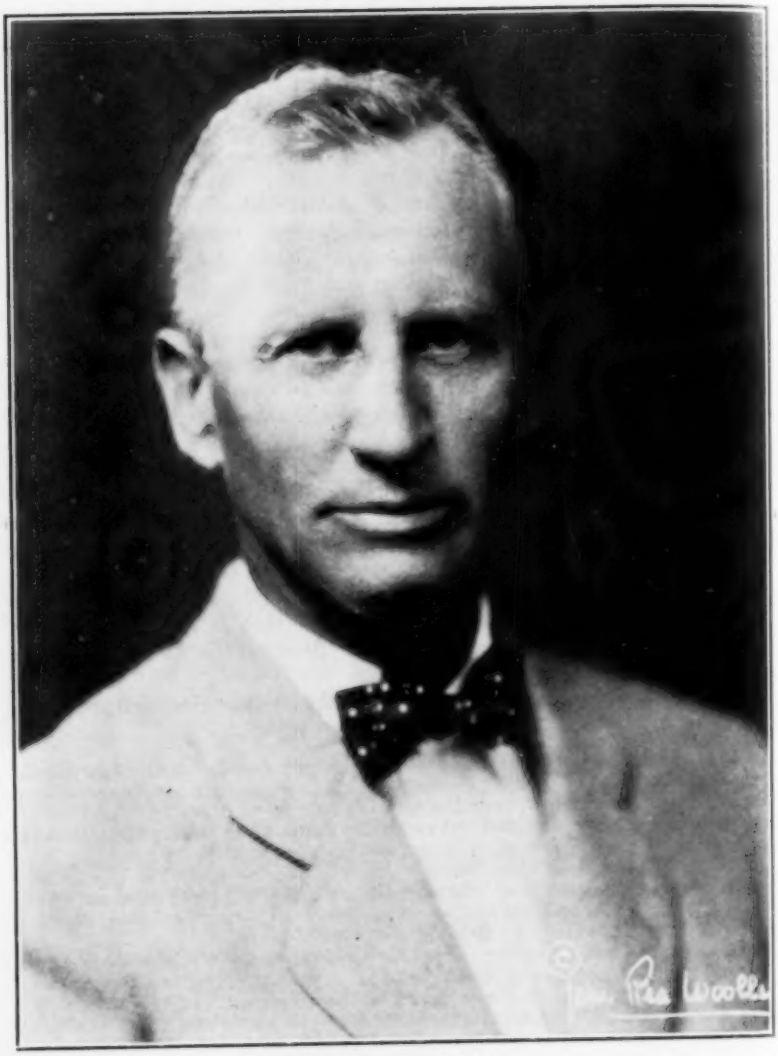
A comparison of the results of mental tests made in the special schools for physically defective children in London with those made on the children who had taken the light treatment at the Lord Mayor Treloar Cripples' Hospital at Alton showed a marked superiority for those who had the advantage of the sunshine. Both groups of children were naturally retarded on account of their disease, but the mental retardation of the London children was on the average 1.95 years, while that of the Alton children was 1.14 years. Both groups were about the same age, 11 years, and the London children had had more schooling.

Sir Henry Gauvain, superintendent of the Treloar Hospital, in reporting these results is careful to add:

> It is not our object to aim a blow at the solidly founded theory that intelligence is innate and can not be increased. It is probably quite indisputable that an individual's amount of mental energy is fixed and unalterable. But it is unalterable in the same way that the maximum power of an engine is unalterable. An engine of a maximum of 40 horsepower can by no trick be made any more powerful. But the ways are legion whereby it can be made less powerful—a dirty sparking plug, a faulty magneto, dust in a delicate piece of mechanism—any of these things, and many others, may reduce its power far below 40. It is suggested that the case is no different with mental energy.
>
> We advance the suggestion, which further investigation may confirm or disprove, that ultra-violet light, shown to be an important factor in effecting tissue change, may thus improve the nutrition of the grey matter of the brain and in this way increase the output of mental activity which we claim follows judicious exposure to light.

A more exact test was made at Alton on a ward containing 20 small children all afflicted with tuberculous disease of the spine, and therefore bound immobile to their beds. The diet and treatment of all were the same, but 10 of the children were given systematic treatment with artificial light. Sir Henry Gauvain reports:

> While the physique of those receiving light treatment showed improvement as compared with the others, the effect on the mentality was even more definite. Those exposed to light were markedly happier, more vivacious, more alert, and, I may add, more mischievous.

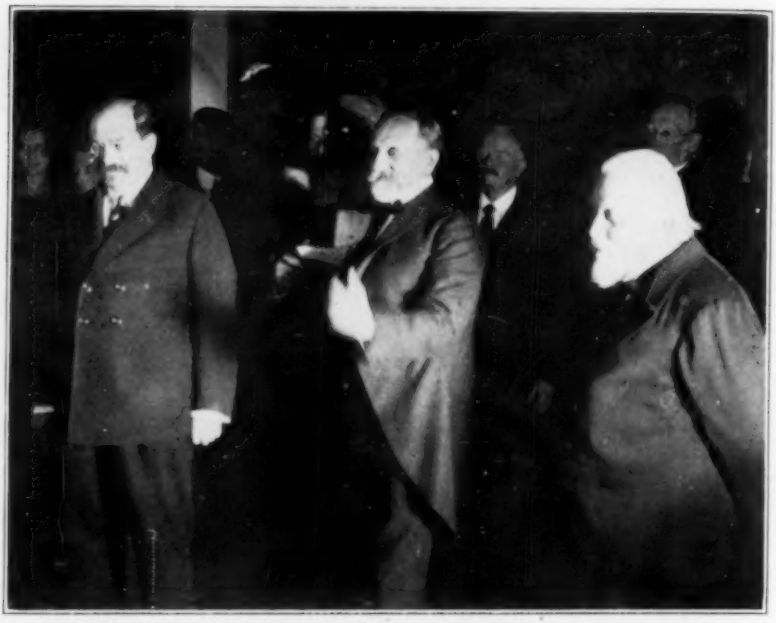


DR. MAX MASON

PRESIDENT OF THE UNIVERSITY OF CHICAGO, FROM 1908 TO 1925 PROFESSOR OF MATHEMATICS IN THE UNIVERSITY OF WISCONSIN.

M. PAINLEVÉ

PRIME MINISTER OF FRANCE AND PROFESSOR OF CELESTIAL MECHANICS IN THE UNIVERSITY OF PARIS. WHEN DISTINGUISHED MATHEMATICIANS ARE HEAD OF THE FRENCH GOVERNMENT AND PRESIDENT OF THE UNIVERSITY OF CHICAGO, THERE MAY BE SOME QUESTION CONCERNING THE COMMON BELIEF THAT MATHEMATICIANS ARE NOT COMPETENT IN PRACTICAL AFFAIRS.



THE TWO HUNDREDTH ANNIVERSARY OF THE RUSSIAN ACADEMY OF SCIENCES

ON THE LEFT, LUNATCHARSKI, PEOPLE'S COMMISSIONER OF EDUCATION; DR. SERGIUS VON OLDENBURG, THE ORIENTAL SCHOLAR, PERMANENT SECRETARY, AND ALEXANDER PETROVIC KARPINSKI, PROFESSOR OF GEOLOGY, PRESIDENT OF THE ACADEMY.

They would often laugh and sing and appeared to be overflowing with animal spirits, while their fellows remained silent.

So, if any parents or teachers find their children are not mischievous enough, they may liven them up a bit by letting a little sunshine in. But not too much or too long at a time. Interrupted and periodic exposure to solar rays is superior to continual treatment. Five or ten minutes at a time at first, gradually increasing so as to produce tanning without burning. And remember that window glass is opaque to the short rays that are wanted. So is clothing, except the very thinnest. Artificial silk, rayon, is more permeable to these rays than natural silk, but even lightest fabric of artificial silk will cut off more than half of the ultra-violet rays. Though it be the brain that one wants to stimulate, "direct action" is dangerous. Hats or eye-shades are usually needed.

Every one who has dabbled in photography knows how variable sunlight is in its proportion of the short waves that affect a sensitive plate, and the same is true of a sensitive skin. Ten minutes of sunning will sometimes raise a blister, and on another day when the daylight seems equally bright one can stand an exposure for hours without blushing or browning. A photographic exposure meter or strip of sensitive paper can serve as a test of the actinic and therapeutic intensity of the light. On account of the variable and uncertain character of sunlight, hospitals often prefer to use the rays given off by the mercury-quartz or carbon arc lamps where the dose can be definitely regulated.

THE TWO HUNDREDTH ANNIVERSARY OF THE RUSSIAN ACADEMY OF SCIENCES

PROFESSOR STEKLOFF, THE MATHEMATICAL PHYSICIST, VICE-PRESIDENT OF THE ACADEMY, WITH DR. C. V. RAMAN, PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CALCUTTA.

COMMERCIAL AVIATION

ABOUT 30,000,000 miles have been flown in regular commercial air service throughout the world, according to a progress report of the survey now being made jointly by the U. S. Department of Commerce and the American Engineering Council.

This distance has been covered under widely varying conditions, over land and water, forests and mountains, by day and night, it was said by Professor Joseph W. Roe, director of the field staff of the joint committee on civil aviation, and head of the Department of Industrial Engineering in New York University, by whom the report was authorized.

This accumulated experience, according to Professor Roe, affords data for comparing the development and present status of civil aviation in this country and in Europe, as to growth and character of service, safety, reliability, financial aspects, government relations, etc. It also gives information on the conditions covering air transport, airways and the industrial use of airplanes as in agriculture, forestry and surveying.

Professor Roe favors a federal air law providing for government, supervision of air transport, and indirect aid to commercial aviation, not necessarily in the form of subsidies.

The Department of Commerce and the American Engineering Council are making a study of civil aviation and gathering data which will be of value as a basis for constructive legislation and for guiding investment in this field.

Information, supplied by foreign attachés, aviation officers, engineers and operators is being brought together covering all the regular air services

THE TWO HUNDREDTH ANNIVERSARY OF THE RUSSIAN ACADEMY OF SCIENCES

PROFESSOR SERGIUS VON OLDENBURG, PERMANENT SECRETARY OF THE ACADEMY, WITH THE TIBETIAN SAVANT, HAMBO-ALVAI-DARULOV, REPRESENTATIVE OF THE DALAI-LLAMA.

throughout the world. The study deals with the commercial operation of aircraft, as distinguished from manufacture, and will not touch on military or naval flying.

The report will cover also the world experience in governmental relations with civil aviation. Every foreign air line is heavily subsidized. This does not necessarily mean that American air lines should have subsidies.

Conditions here are more favorable for commercial aviation than abroad, but it can not even hope to succeed without those indirect aids which have been extended to land and water transportation throughout our entire history.

Few realize the extent of such aid, which amounts to about $200,000,000 for the current fiscal year 1925–26 and covers such items as coast and hydrographic surveys, light-house service, weather bureau, river and harbor improvements and rural post roads.

The establishment of aids such as airways, beacons, airports, meteorological and radio services is only applying to air transport the policy long

followed with the older forms of transportation, and without which they could not operate.

A second phase is air legislation. We have as yet no federal air laws and no supervision of air transport. Any inexperienced pilot with any second-hand plane, who can induce a passenger to go into the air with him is free to do so, a condition unthinkable at sea.

There should be a federal air law placing air transport under such proper government supervision as will insure safety. It should be general in character and flexible enough to allow adjustment to the changing conditions of a rapidly developing situation.

It should conform as far as possible to the International Convention for Air Navigation, which is the basis of the air laws of all countries. In Canada such a law has been in operation for five years and is giving general satisfaction.

The survey in hand is gathering the experience of other countries with their air laws to aid in the formulation of similar legislation in this country.

A complete report on the survey, the first of the kind to be attempted either in this country or abroad, will be presented to the Administrative Board of the American Engineering Council at a meeting fixed for October 29 and 30 at Columbus, Ohio.

The chairman of the committee on civil aviation is J. Walter Drake, assistant secretary of commerce, and other members are: Dr. W. F. Durand, president of the American Society of Mechanical Engineers; Professor E. P. Warner, Massachusetts Institute of Technology; L. K. Bell, Washington, former traffic manager of Air Mail, and C. T. Ludington, Philadelphia, general aircraft operator. Working in the field with Professor Roe are J. Parker Van Zandt, U. S. Air Service, who has recently made an extensive study of civil aviation abroad, and Professor Alexander Klemin, head of the aeronautical engineering course in New York University.

THE TRANSMUTATION OF MERCURY INTO GOLD

WHAT appears to be increasing success in the effort of German science to transform mercury into gold is reported in Cothen advices to the American Chemical Society.

In one year, these advices state, ten thousand times as much gold has been produced from the same quantity of mercury through the experiments carried on by Professors Miethe and Stammreich.

Gold has also been obtained, it was said, at the Siemens Works in Berlin by bombarding mercury surfaces with electrons in extremely high vacuum.

The work of Miethe and Stammreich, it was stated, is dispelling the doubt that existed among eminent German chemists, among them Fritz Haber, internationally famous for his development of synthetic ammonia, a large factor in German war plans. Attempts to derive gold from mercury in the United States by the same methods have failed.

The message to the American Chemical Society from its Cothen correspondent says the skepticism which was fostered privately and publicly toward the experiments of Professors Miethe and Stammreich on the transformation of mercury into gold dwindled when investigators reported before the German Chemical Society the results of their more recent experiments.

Professor Haber, who previously cherished the greatest doubt as to the accuracy of the experiments, congratulated Professor Miethe and re-

—Henry Miller News Picture Service, Inc.

THE BRITISH MOSQUITO CONTROL INSTITUTE

THE NEW HOME OF THE BRITISH MOSQUITO CONTROL INSTITUTE IN LONDON, ENGLAND, OPENED BY SIR RONALD ROSS, K.C.B., F.R.S. THE BUILDING WILL BE USED TO EXPERIMENT ON CONTROLLING THE MOSQUITO PEST IN THE BRITISH ISLES.

lated how on his world tour he had seen in the laboratory of Professor Nagaoka, at Tokyo, the apparatus with which the latter, later, but independently of Miethe, had likewise obtained gold from mercury, and that he himself could confirm the results by repetition of the experiment.

If electrical discharges are passed between mercury electrodes in a dielectric, that is, paraffin, the gold is found only in the mercury atomized in the spark path and at concentrations of gold to mercury as one part to ten thousand, that is, from one kilogram of mercury is obtained 0.1 gram or 100 milligrams of gold.

Up to the time of the first publications, Miethe had obtained one part of gold from 100,000,000 parts of mercury. Thus, in about a year success has been attained in increasing ten thousand fold the yield of gold from the same amount of mercury. Likewise in the laboratory of the Siemens Works in Berlin they have succeeded in obtaining gold after bombarding mercury surfaces with electrons in extremely high vacuum.

It is to be emphasized that all methods thus far applied permit practically complete recovery of the mercury so that the same quantity can be used repeatedly.

Theoretically this is comprehensible even if it is assumed that only the one isotope of mercury, with the atomic weight 197, is subjected to transformation; for the amount of this isotope far surpasses the amounts of gold so far obtained.

The silver-like substance which often appears with the gold, or is formed almost exclusively, arises likewise, according to Miethe, from the mercury. Professor Nagaoka has also obtained, together with gold, a second substance which he described as similar to platinum.

—*Wide World Photos*

"THE DISCOVERY"

LEAVING DARTMOUTH, ENGLAND, UNDER FULL SAIL FOR A SCIENTIFIC VOYAGE TO THE POLAR REGIONS.

HOW TO FIND THE NORTH STAR

Two well known and easily recognized groups of stars, Cassiopeia and Andromoda, furnish an excellent means of locating the North Star, Polaris, in the late fall and early winter evening when they are to be found high in the heaven above the pole. The time-honored method of finding the North Star by means of "The Pointers" in the Big Dipper, though one of the best, can not be used to advantage at this time of year especially by the unfortunate individuals who try to do their star-gazing from city streets. For the Big Dipper now rests nearly on the northern horizon and any obstruction in this direction, such as buildings or trees, conceals it more or less from view.

Cassiopeia, which can be quickly identified by its W-shaped grouping of stars and which is almost as well known as the Big Dipper, is on the opposite side of the pole from the Big Dipper so that when the Big Dipper is near the horizon Cassiopeia rides high in the heavens, and vice versa. To the south of Cassiopeia and about as far from Cassiopeia as Cassiopeia is from the north pole of the heavens will be found the three second magnitude stars in a line slightly concave toward the pole which outline the constellation of Andromeda. The most westerly of these three stars, Alpha Andromeda, is in the northeast corner of the Great Square in Pegasus which lies next to Andromeda on the west. Now let us locate the North Star with the aid of these two groups. Alpha Andromeda, which we have just identified, and Beta Cassiopeiae, which is the star farthest west in the W of Cassiopeia, lie almost exactly in a straight line with Polaris the North Star. Beta Cassiopeiae is midway between the other two stars. Also Gamma, in Andromeda, the farthest east of the three stars in Andromeda, and Epsilon, in Cassiopeia, the third magnitude star farthest east in the W of Cassiopeia, lie in another straight line with the star in Cassiopeia again midway between the other two stars. In other words, two lines drawn, respectively, through the stars at the eastern and at the western extremities of the W of Cassiopeia and of the line of three bright stars in Andromeda meet at the North Star. A little practice will enable one to locate the Pole Star very quickly and easily in this way.

Practically every one knows the Big Dipper in Ursa Major, the Greater Bear, but the Little Dipper formed by seven of the stars in Ursa Minor, the Lesser Bear, is not so well known because it contains fewer bright stars than the Big Dipper. Polaris, the Pole Star, or North Star, at the end of the handle of the Little Dipper is a star of the second magnitude. The two stars that correspond in position to the pointers of the Big Dipper, that is, that lie in the bowl farthest from the handle, are of the second and third magnitude, respectively, but of the four remaining stars two are of the fourth magnitude and two of the fifth, and therefore inconspicuous. Yet it is not a difficult matter to make out the outline of the Little Dipper on a clear night and with its aid we can check up on the position of Polaris by recalling that it is located at the end of the handle.

There are times when we may find it very convenient to be able to get our bearings by the North Star. Every one should know at least one way of locating the important star.—Isabel M. Lewis, *Science Service.*